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DANA'S WORKS.

IVISON, BLAKEMAN, TAYLOR & Co., New York.—**Manual of Geology,** by J. D DANA. **Third Edition,** 1880. 912 pp. 8vo. $5.00.—**Text-book of Geology** by the same. **4th ed.** 1883. 412 pp. 12mo. $2.00.—**The Geological Story Briefly Told,** by the same. 264 pp. 12mo. 1875.

J. WILEY & SONS, New York.—**Treatise on Mineralogy,** by J. D. DANA. 5th edit. xlviii and 828 pp. 8vo., 1868. $10.00. The 5th "subedition" was issued by Wiley & Son in April, 1874. (Each "subedition" (or issue from the stereotype plates), contains corrections of all errors discovered in the work up to the date of its publication). Also, Appendix I. by G. J. Brush, 1872. Appendix II, by E. S. Dana, 1875.—**Manual of Mineralogy & Lithology,** by J. D. DANA. 3d edition 474 pp. 12mo., 1878.—**Text-book of Mineralogy,** by E. S. DANA. Revised edition. 512 pp. 8vo., 1883.—**Text-book of Elementary Mechanics,** by E. S. DANA. 300 pp. with numerous cuts, 12mo., 1881.—**Manual of Determinative Mineralogy,** with an Introduction on Blow-pipe Analysis, by GEORGE J. BRUSH. 8vo., 2d ed. 1877. Third Appendix to Dana's Mineralogy, by E. S. DANA. 136 pp. 8vo. 1882.

DODD & MEAD, New York.—**Corals and Coral Islands,** by J. D. DANA. 398 pp. 8vo, with 100 Illustrations and several maps. 2d ed., 1874.

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[THIRD SERIES.]

ART. XXVIII.—*Contributions to Meteorology;* by ELIAS LOOMIS, Professor of Natural Philosophy in Yale College. Twenty-second paper. With Plate V.

Areas of high pressure. Their magnitude and direction of movement. Relation of areas of high pressure to areas of low pressure.

IN several former papers I have examined the form and magnitude of areas of high pressure, the position of the major axis of the isobars, the direction and velocity of their movement, and the low temperature which accompanies them—the laws of the wind's motion within these areas—the circumstances under which areas of high pressure originate, and the relations which they bear to areas of low pressure. This examination has been made for the United States by the aid of the Signal Service maps and the published volumes of the Signal Service observations; and it has been made for Europe by the aid of Hoffmeyer's Weather Maps. It was found that areas of unusually high pressure sometimes extend from the Pacific Ocean to the Atlantic; and stretch northward far beyond the limits of the United States. The maps of the United States Signal Service are therefore not large enough to exhibit satisfactorily the phenomena of areas of unusually high pressure, and especially to exhibit their relations to areas of low pressure; and the same is true of Hoffmeyer's charts of the Atlantic Ocean and Europe. I have therefore extended this examination to the maps of the

International Bulletin. These maps begin with Oct., 1877 and extend to June, 1884. Table I exhibits all the cases which I have found in which these maps show an isobar of 31·0 inches over any part of the Northern Hemisphere. Columns 3 and 4 show the latitude and longitude of the station at which the barometer was highest. This station is generally near the center of the highest isobar but may not coincide exactly with it. Columns 5 and 6 show the pressure and temperature at the station. where the barometer was highest. Columns 8 and 9 show (in degrees of a meridian) the dimensions of the high area measured in an East and West direction, and also in a North and South direction. Since a large part of the isobars represented on the maps are incomplete, I have extended them about each high center up to the isobar 30·0 inches in such a manner as seemed to correspond best to the incomplete curves shown on the maps. The numbers in columns 8 and 9 give the results obtained for the isobars thus completed. The lines measured in the two different directions run nearly through the centers of the high areas. In many cases the high areas stretch out to a great distance toward the East and West, particularly in a latitude somewhat south of the high center. In such cases the numbers in column 8 do not indicate the full extent of the isobar, 30·0 inches, but only its extent near the parallel which passes through the center of high pressure.

TABLE I.—*Barometer above* 31·0 *inches, International Bulletin.*

No.	Date.	Lat.	Long.	Barom. highest.	Therm. Fahr.	Therm. below mean.	Breadth, Deg. E.-W.	Breadth, Deg. N.-S.
		°	°		°	°	°	°
	1877, Dec. 14	56·8	60·6 E.	31·37	−31	−38	--	60
	15	53·3	83·8 E.	·30	−55	−61	--	55
	16	53·3	83·8 E.	·63	−54	−60	90	58
1	17	53·3	83·8 E.	·63	−50	−56	88	57
	18	53·3	83·8 E.	·45	−41	−47	68	59
	19	58·4	92·1 E.	·37	−17	− 8	78	59
	20	55·8	49·1 E	·26	1	−12	80	56
	21	53·8	48 6 E.	·08	6	− 7	80	51
	Dec. 31	58·4	92·1 E.	·08	−21	−11	74	46
	1878. Jan. 1	58·4	92·1 E.	·01	−26	−16	80	48
	2	53·8	48·6 E.	·02	− 6	−17	79	45
	3	53·8	48·6 E.	·01	− 1	−12	76	41
2	4	41·3	69·3 E.	·09	−10	−40	83	44
	5	41·3	69·3 E.	·02	− 4	−34	76	47
	6	58·4	92·1 E.	·06	−28	−16	71	52
	7	58·4	92·1 E.	·25	−30	−18	--	60
	8	58·4	92·1 E.	·15	−28	−16	63	58
	9	58·4	92·1 E.	·20	−33	−21	--	62
3	Dec. 11	53·3	83·8 E.	·09	−42	−48	66	55

TABLE I—*continued.*

No.	Date.		Lat.	Long.	Barom. highest.	Therm. Fahr.	Therm. below mean.	Breadth, Deg.	
								E.-W.	N.-S.
	Dec.	20	58°4	92°1 E.	·01	−28°	−19°	58°	60°
		21	58·4	92·1 E.	·08	−35	−26	70	60
4		22	58·4	92·1 E.	·22	−39	−30	61	63
		23	58·4	92·1 E.	·26	−36	−27	76	60
		24	58·4	92·1 E.	·10	−18	− 9	67	64
5	Dec.	28	58·4	92·1 E.	·09	− 0	+ 6	80	60
	1879. Jan.	18	56·8	60·6 E.	·00	−15	−20	70	56
		19	56·8	60·6 E.	·12	−22	−27	84	55
6		20	53·3	83·8 E.	·25	−28	−27	85	66
		21	53·3	83·8 E.	·15	−23	−22	..	67
		22	55·8	49·1 E.	·09	− 4	−13	83	63
		23	55·8	37·7 E.	·09	3	−12	76	65
7	Feb.	24	56·8	60·6 E.	·00	− 3	−15	..	53
8	Nov.	24	41·3	69·3 E.	·00	13	−30	72	28
9	Dec.	25	41·2	112·0 W.	·14	− 3	....	..	..
	1880. Jan.	16	58·4	92·1 E.	·07	−33	−21	70	56
		17	51·3	119·6 E.	·03	−35	−13	60	60
10		18	51·3	119·6 E.	·10	−35	−13	..	60
		19	58·4	92·1 E.	·17	−16	− 7	..	59
		20	51·3	119·6 E.	·16	−27	−10	..	62
11	Jan.	24	58·4	92·1 E.	·00	−14	− 4	58	62
12	Jan.	28	51·3	119·6 E.	·02	−33	−11	..	61
		29	51·3	119·6 E.	·15	−36	−14	..	68
	1881. Mar.	1	58·4	92·1 E.	·36	−10	−24	67	54
13		2	58·4	92·1 E.	·41	− 9	−23	..	57
		3	58·4	92·1 E.	·22	0	−14	..	62
14	Mar.	9	58·4	92·1 E.	·02	− 3	−17	..	62
15		23	53·3	83·8 E.	·02	17	− 1	50	46
16	Nov.	4	58·4	92·1 E.	·07	5	− 4	..	44
17	Dec.	14	58·4	92·1 E.	·08	− 7	0	73	62
		15	58·4	92·1 E.	·06	−14	− 8	73	63
18	Dec.	27	58·4	92·1 E.	·04	− 9	− 3	78	50
19	1882. Jan.	4	51·2	71·4 E.	·01	−28	−30	71	42
20		15	52·2	21·0 E.	·06	28	+ 3	77	50
21		23	49·8	97·1 W.	·03	−35	....	32	52
22	Feb.	17	49·8	97·1 W.	·09	−29	....	25	55
23		20	49·9	7·8 W.	·20	−50	0	..	50
24	Oct.	28	50·4	80·2 E.	·05	− 7	−46	87	47
25	Nov.	13	58·4	92·1 E.	·13	−15	−22	..	55
26	Nov.	22	50·4	80·2 E.	·06	2	−18	62	46
		23	50·4	80·2 E.	·16	− 4	−24	64	44
27	Dec.	7	39·3	94·9 W.	·01	− 5	....	38	46
28	Dec.	7	58·4	92·1 E.	·03	−42	−33	50	56
29	Dec.	9	56·5	85·0 E.	·01	−37	−39	82	59
		10	50·4	80·2 E.	·04	−27	−33	76	58
	Dec.	13	50·4	80·2 E.	·11	−27	−33	83	47
		14	50·4	80·2 E.	·01	−29	−35	90	51
		15	58·4	92·1 E.	·11	−31	−22	70	51
30		16	50·4	80·2 E.	·12	− 9	−15	77	56
		17	58·4	92·1 E.	·24	−29	−20	77	67
		18	58·4	92·1 E.	·08	−19	−10	74	71
		19	58·4	92·1 E.	·01	−13	− 7	80	78
31	Dec.	29	53·3	83·8 E.	·04	−15	−18	62	51
		30	58·4	92·1 E.	·06	−19	− 9	60	54
32	1883. Feb.	11	63·8	162·0 W.	·21	− 4	0	66	59
33	Nov.	9	52·3	104·3 E.	·05	3	−11	80	47
		10	52·3	104·3 E.	·03	0	−14	75	56
34	Nov.	15	58·6	49·7 E.	·00	24	0	90	61
35	Dec.	22	58·4	92·1 E.	·02	−12	− 6	77	60
36	1884. Jan.	18	51·3	119·6 E.	·02	−32	−10	65	68
		19	51·4	119·6 E.	·01	−27	−10	80	68
37	Jan.	23	50·7	103·7 W.	·03	−36	....	57	39

Of the 81 cases enumerated in this table, the number for each month in the year was as follows:

January, 29; February, 4; March, 5; October, 1; November, 8, and December, 34. We thus see that 79 per cent of the whole number of cases occurred in the months of December and January; and none occurred during the six warmer months of the year.

Of these 81 cases, 74 occurred over Europasia; 6 over North America and one over the Atlantic Ocean near the Southwestern extremity of Ireland. Table II shows the latitude and longitude of the 74 stations over Europasia at which a pressure above 31·0 inches was recorded; and also the number of cases occurring at each of these stations.

TABLE II.—*Latitude and longitude of the high centers.*

Station.	Lat.	Long.	Cases.	Station.	Lat.	Long.	Cases.
Viatka	58°·6	49°·7 E.	1	Barnaul	53°·3	83°·8 E.	9
Yeniseisk	58·4	92·1	32	Irkutsk	52·3	104·3	2
Ekaterinburg	56·8	60·6	4	Warsaw	52·2	21·0	1
Tomsk	56·5	85·0	1	Nertchinsk	51·3	119·6	7
Kasan	55·8	49·0	2	Akmolinski	51·2	71·4	1
Moscow	55·8	37·5	1	Semipalatinsk	50·4	80·2	7
Krotkowo	53·8	48·6	3	Taskend	41·3	69·3	3

With but one exception, these stations are all situated between the parallels of 50° and 60°. Taskend, being situated so far south of the other stations, has a suspicious appearance. According to the International Bulletin its altitude above sea level is 1607 feet, but the altitude is marked by ? as if considered doubtful. It seems probable that the assumed elevation is a little too great, and that the barometric pressure, reduced to sea level, is consequently somewhat too great. With but one exception, all of the 81 cases included in Table I are situated over the continents, and almost invariably at a considerable distance from both the Atlantic and Pacific Oceans, and the exception named occurred near the coast of Ireland. Not a single case of pressure amounting to 31·0 inches has been found over the Pacific Ocean, although one case occurred in the northwestern part of North America near Behring Strait. These facts clearly show the influence of the continents in favoring the formation of areas of very high pressure; and over Europasia these cases occur chiefly between the parallels of 50° and 60°.

The observations in Table I indicate that these high areas are nearly stationary in position. At each station from day to day there are slight fluctuations of pressure which give to the high center the appearance of moving rapidly to and fro, but

in general for the 14 cases in which the pressure of 31·0 inches was maintained for at least two successive days, the position of the high center on the last day did not differ greatly from its position on the first day. In No. 1 the high center did not fluctuate greatly in position for eight days, but apparently advanced a little toward the south and west. No. 2 continued for ten days, and on the last day the center was found at the same station as on the first day. No. 4 remained stationary for five days; No. 12 stationary for two days; No. 13 for three days; Nos. 17, 26, 33 and 36 stationary for two days; No. 6 moved slightly toward the south and west; No. 10 moved slightly toward the south and east; No. 30 continued for seven days and apparently moved a little toward the north and east; No. 31 also appeared to move a little toward the north and east. We thus find that in the 14 cases in which the pressure of 31·0 inches was maintained for at least two successive days, in eight of them the center apparently made no progress; in three cases there was a slight movement toward the east, and in three cases a slight movement toward the west; in two cases there was a slight movement toward the north, and in four cases a slight movement toward the south. The facts all indicate that these high areas had no very distinctly marked progressive movement.

The mean diameter of these high areas measured in a direction from north to south (which was generally the shortest diameter) is 55 degrees of a meridian, or about 3800 English miles. The mean diameter in an East and West direction is 71 degrees of a meridian, or about 4900 English miles; and if we had measured the actual extent of the isobar 30·0 inches near a parallel a little south of the high center, we should have found considerably larger dimensions.

The low temperature attending these high areas is quite remarkable, the mean temperature from the 74 cases over Europasia being −18° Fahr.; and the observations were taken at 7 A. M. Washington time, which for the center of Europasia is near the warmest part of the day. Column 7th of Table I shows how much the thermometer at each station was depressed below its mean height for the given time and place. The average of the numbers in this column is −19° F., which is considerably less than for like cases in the United States; but this appears to be mainly due to the fact that in Central Asia the thermometer is almost uninterruptedly low at this season of the year. There were however several cases in which the thermometer was but slightly below its mean height, and there were two cases in which the thermometer was slightly above the mean. In Table III, I have given all the cases in which the depression of the thermometer below its mean height

for the given time and place was less than 6 degrees, and I have added various particulars which are designed to shed some light upon the cause of this peculiarity. Column 1st gives the dates of the cases; column 2d gives the station of highest pressure; column 3d gives the depression of the thermometer below its mean height at this station. Column 4th shows the degree of cloudiness at this station (scale 0–10); column 5th gives a station not very remote from the preceding where the thermometer was more depressed below the mean; column 6th shows the temperature at this station; column 7th shows how much the thermometer at this station was depressed below the mean, and column 8th gives several stations where the sky was entirely overcast with clouds, and at most of these stations there was some precipitation in the form of snow or rain.

TABLE III.—*Cases of unusually high temperature with high pressure.*

Date.	Maximum pressure.	Below mean.	Cloud.	Extreme cold.			Sky entirely overcast.
				Station.	Therm.	Below mean.	
1878. Dec. 28	Yeniseisk.	+6°	0	Irkutsk.	−29°	−10°	Turuchansk, Kainsk. Irkutsk.
1880. Jan. 24	Yeniseisk.	−4	0	Ekaterinb.	−17	−22	Turuchansk, Ekaterinburg.
1881. Mar. 23	Barnaul.	−1	1	.....	....	....	Turuchansk, Ekat. Kainsk.
Nov. 4	Yeniseisk.	−4	9	Barnaul.	− 2	−19	Turuch., Tomsk, Akmolinsk.
Dec. 14	Yeniseisk.	0	4	Barnaul.	−12	−18	Turuchansk, Akmolinsk, Ekat.
27	Yeniseisk.	−3	10	Barnaul.	−23	−29	Yeniseisk,,Turuchansk. Ekat.
1882. Jan. 15	Warsaw.	+3	1	Kiew.	+14	− 9	Dorpat, Moscow, Munich.
Feb. 20	N. Ireland	0	8	.....	....	....	Valencia, Plym., Bordeaux.
1883. Nov. 15	Viatka.	0	10	Semipalat.	+ 6	−14	Viatka, Dorpat, Kasan.

We see that in these cases there was generally a station not very remote from the center of high pressure where the thermometer was more depressed than it was at the high center, which agrees with what has been found for the United States. We also see that in only two of the cases was the sky at the center of high pressure entirely free from clouds, and in each case there were stations not very remote where the sky was entirely overcast and there was some precipitation in the form of rain or snow. These facts seem to indicate that the comparatively high temperature attending these high areas was due to local disturbances which gave rise to cloudiness and the consequent development of heat.

In order to ascertain whether an unusually low temperature in Central Asia is generally attended by a barometric pressure considerably above the mean, I have selected all the cases in which the thermometer at Yeniseisk fell as low as −36° C., during a period of seven years (1876–1882) and opposite to each temperature I have placed the barometric pressure for the same dates. The particulars are shown in Table IV.

TABLE IV.—*Thermometer —36° Cent. at Yeniseisk, Central Asia.*

Date.	Ther.	Bar.	Above mean.	Date.	Ther.	Bar.	Above mean.	Date.	Ther.	Bar.	Above mean.
1876.				1877.				1879.			
Jan. 7	−39°1	772·5	+ 8·7	Dec. 27	−37°8	774·4	+ 8·8	Nov. 28	−37°3	761·1	− 0·1
8	−38·0	73·8	+10·0	1878.				29	−40·6	72·4	+11·2
31	−36·1	62·7	− 1·1	Jan. 2	−37·0	72·8	+ 9·0	1880.			
Feb 1	−45·9	65·1	+ 3·9	7	−39·2	80·8	+17·0	Jan. 16	−38·8	78·5	+14·7
7	−38·2	63·9	+ 2·7	8	−38·2	83·1	+19·3	17	−41·5	80·0	+16·2
13	−38·2	57·1	− 4·1	9	−39·5	80·6	+16·8	19	−36·7	82·6	+19·8
14	−40·3	51·6	− 9·6	10	−38·7	79·9	+16 1	26	−36·1	72·0	+ 8·2
Nov. 30	−39·0	71·0	+ 9·8	25	−37·8	71·8	+ 8·0	Feb. 16	−36·1	75·2	+14·0
Dec. 1	−43·1	73·2	+ 7·6	26	−37·7	76·8	+13·0	17	−37·0	73·7	+12·5
13	−36·9	75·0	+ 9·4	27	−37·1	74·3	+10·5	18	−38·2	68·9	+ 7·7
14	−39·0	73·1	+ 7·5	28	−37·6	72·1	+ 8·3	Dec. 10	−37·6	70·2	+ 4·6
29	−37·7	72·9	+ 7·3	Feb. 1	−37·0	67·9	+ 6·7	11	−37·9	72·8	+ 7·2
1877.				Nov. 5	−37·4	69·2	+ 8·0	12	−38·0	76·9	+11·3
Jan. 9	−39·7	81·5	+17·7	Dec. 5	−36·6	56·5	− 9·1	1881.			
10	−46·1	81·8	+18·0	6	−41·0	59·9	− 5·7	Feb. 2	−39·2	76·7	+15·5
18	−36·1	62·4	− 1·4	7	−36·6	68·1	+ 2·5	12	−40·0	77·2	+16·0
20	−36·4	62·7	− 1·1	8	−38·0	65·6	0·0	21	−37·3	63·1	+ 1·9
21	−46·6	64·6	+ 0·8	9	−44·9	69·9	+ 4·3	22	−36·8	72·6	+11·4
22	−48·8	74·9	+11·1	10	−48·0	74·4	+ 8·8	23	−39·6	68·8	+ 7·6
28	−42·4	60·3	− 3·5	11	−40·3	77·6	+12·0	Mar. 1	−37·1	84·0	+23·7
29	−45·5	67·5	+ 3·7	13	−37·6	77·9	+12·3	Nov. 29	−37·0	68·3	+ 7·1
30	−41·7	68·3	+ 4·5	21	−42·9	78·7	+13·1	30	−38·0	70·0	+ 8·8
31	−36·1	74·1	+10·3	22	−42·9	82·2	+16·6	Dec. 1	−38·0	66·3	+ 0·7
Feb. 4	−36·1	64·9	+ 3·7	23	−40·2	82·7	+17·2	2	−36·6	65·7	+ 0·1
5	−41·7	63·9	+ 2·7	1879.				23	−36·2	71·1	+ 5·5
6	−38·1	66·1	+ 4 9	Jan. 17	−41·0	63·1	− 0·7	1882.			
7	−37·8	71·4	+10·2	18	−50·0	66·9	+ 3·1	Dec. 1	−41·8	58·3	− 7.3
8	−36·8	72·6	+11·4	19	−54·1	73·5	+ 9·7	3	−42·0	64·6	− 1.0
9	−40·6	75·0	+13·8	20	−46·6	74·1	+10·3	6	−38·4	73·4	+ 7·8
Dec. 11	−38·5	51·6	−14·0	24	−38·0	72·0	+ 8·2	7	−46·7	77·2	+11·6
12	−46·4	61·9	− 3·7	25	−42·7	73·8	+10·0	8	−49·0	76·3	+10 7
13	−50·7	65·1	− 0·5	26	−43·7	74·4	+10·6	9	−48·6	75·5	+ 9·9
14	−50·5	72·8	+ 7·2	27	−43·9	66·3	+ 2·5	17	−39·6	84·4	+18·8
15	−46·5	81·1	+15·5	Feb. 15	−38·4	68·5	+ 7·3	24	−42·1	75·3	+ 9·7
16	−44·5	87·9	+22·3	16	−45·4	74·9	+13·7	25	−44·4	77·9	+12·3
23	−37·6	77·0	+11·4	17	−40·5	69·7	+ 8·5	26	−40·8	76·6	+ 5·0
26	−37·0	76·7	+11·1	22	−37·7	69·2	+ 8·0				

The mean pressure at Yeniseisk (not reduced to sea level) is as follows: January 763·8^{mm}; February 761·2^{mm}; March 759·3^{mm}; November 761·2^{mm}; December 765·6^{mm}. From these values I have deduced the numbers given in column 4th of the table, showing for each date in millimeters how much the barometer was above or below its mean height. The average of the numbers in this column is +7·8^{mm} (=0·31 inch); that is when the thermometer at Yeniseisk sinks as low as −36° C. the barometer is generally 0·31 inch above its mean height. In only one case (Dec. 16, 1877) did the barometer rise as high as 31·0 inches. We find then that extremely low temperatures are generally attended by a pressure somewhat above the mean, but seldom by an extremely high pressure. Moreover we find

15 cases (one-seventh of the whole number) in which the pressure was below the mean.

The most remarkable case of low pressure occurred Dec. 11, 1877. On the 9th of December there was an area of low pressure near Yeniseisk (29·63 inches) accompanied by a temperature very much above the mean. On the next day the barometer rose slowly and the thermometer sunk rapidly. On the 11th the thermometer continued to sink and the barometer also descended slightly, but the stations of observation are not sufficiently numerous to indicate clearly the cause. For six successive days the thermometer remained below −36° C. and the barometer rose steadily, standing at 790·4^{mm} at 9 P. M. Dec. 16th. This cold wave came from the northeast and preceded the high pressure, and the high pressure of Dec. 16th was apparently the effect of the long continued and severe cold which preceded it.

The case of Dec. 5 and 6, 1878, was similar to the preceding. On the 4th of December there was an area of low pressure near Yeniseisk (29·69 inches) accompanied by a high temperature. On the next day the thermometer fell rapidly, but the barometer rose slowly. The thermometer continued very low until the 13th, and the barometer rose steadily during the same period, with the exception of a slight check on the 8th, the reason of which does not fully appear. In this case the cold wave appeared to come from the northeast, and preceded the high pressure which was apparently the effect of the long continued and extreme cold.

The case of Feb. 14, 1876, was similar to the preceding. On the 10th of February there was an area of low pressure near Yeniseisk (29·06 inches) accompanied by a temperature much above the mean. After this, the thermometer sunk steadily until the morning of the 14th, and the barometer rose slowly until the 13th.

The case of Dec. 1, 1882, was also similar to the preceding. On the 28th of November there was an area of low pressure near Yeniseisk (29·68 inches) accompanied by a high temperature. After this, the thermometer fell rapidly, but the barometer rose slowly.

All of these exceptional cases appear to have been preceded by an area of low pressure, after which the barometer rose slowly but the thermometer sunk rapidly, and this sudden fall of the thermometer appears to have resulted mainly from the previous existence of a cold area in the northeast, which cold air pressed rapidly into the area of low pressure as soon as the barometer began to rise.

We have thus found that over Europasia, areas of high pressure frequently cover a vast extent of territory; the barometer

rises to a height unknown in any other part of the world; the thermometer sinks very low; and the center of the high area, although it vibrates to and fro, from day to day, appears to have no decided progressive motion. The highest pressure shown in table I is 31·63 inches at Barnaul, and is the highest pressure at any of the stations reported in the International Bulletin. The number of Russian stations from which reports were received is only 22, whereas the number reported in the Annalen des Physikalischen Central Observatoriums is over 100, and one of these stations shows a pressure higher than Barnaül. At Ssemipalatinsk, on Dec. 16th, 1877, the pressure was 784·5^{mm}, which reduced to sea level (altitude 607 feet and temperature − 49° Cent.) amounts to 31·72 inches. This is the highest pressure I have found reported at any time for any part of the globe.

These high areas are characterized by another circumstance no less remarkable, viz: their long duration. For eight successive days from Dec. 14th, 1877, a pressure of 31·0 inches was maintained near the center of Europasia, and it was renewed on the 31st to continue for ten successive days. Moreover between these two periods, the high area steadily maintained its position, and the pressure at the center at no time sunk below 30·78 inches. A high area had also existed in nearly the same region for twelve days preceding Dec. 14th, and it continued for eleven days succeeding Jan. 9th, so that for 50 successive days there was an area of high pressure covering nearly the whole of Europasia, exhibiting considerable fluctuations in magnitude, but having no very decided progressive movement, and during this whole period the pressure at the center never fell as low as 30·5 inches. In order to exhibit these phenomena more clearly I have prepared table V, which shows the most important facts which can be collected from the International Bulletin.

The arrangement is similar to that of preceding tables. Columns 2 and 3 show the position of the station where the barometer was highest, and the six succeeding columns show the pressure, temperature, humidity, direction and force of the wind, and amount of cloudiness at the same station.

On Dec. 2d the isobar of 30 inches enclosed the principal part of Europasia. The barometer at Archangel stood at 30·58 inches, and at Kasan it stood at 30·55 inches, the center of the high area being near lat. 60°. The temperature was somewhat above the mean for that season of the year, and the winds blew outward from the high area, at some places with considerable force. Apparently this high pressure resulted from the air which rose from an area of low pressure prevailing near South Greenland, which air moved eastward and settled down over

TABLE V.—*Long continued high pressure over Europasia.*

Date.		Lat. North.	Long. East.	Barom. highest.	Therm. Fahr.	Relative humidity	Wind. From.	Wind. Veloc.	Clouds.
1877.									
Dec.	1	53·3	83·8	30·48	+ 5°	91	Calm.	0	0
	2	64·5	40·5	·58	+26	96	E.S.E.	18	10
	2	55·8	49·1	·55	+18	63	Calm.	0	0
	3	56·5	60·6	·73	+ 6	100	Calm.	0	0
	4	55·8	37·7	·74	+19	100	S.	9	10
	5	55 8	37·7	·75	+21	98	S.S.E.	4	10
	6	55·8	37·7	·80	+11	93	S.	7	0
	7	55·8	37·7	·73	+15	91	S.	9	7
	8	41·3	49·3	·63	+27	87	Calm.	0	3
	9	41·3	49.3	·64	+30	94	Calm.	0	0
	10	55·8	37·7	·52	+15	94	S.	7	5
	11	55·8	37·7	·60	+12	93	S.	9	10
	12	53·8	48 6	·68	+25	88	N.W.	4	10
	13	56·8	60·6	·87	−22	79	Calm.	0	0
	14	56 8	60·6	31·37	−31	76	Calm.	0	1
	15	53·3	83·8	·30	−55	73	Calm.	0	0
	16	53·3	83·8	·63	−54	74	S.	2	0
	17	53·3	83·8	·63	−50	72	Calm.	0	1
	18	53·3	83·8	·45	−41	75	Calm.	0	10
	19	58·4	92·1	·37	−17	83	Calm.	0	0
	20	55·8	49·1	·26	+ 1	95	Calm.	0	2
	21	41·3	69·3	.08	+ 2	85	Calm.	0	10
	22	58·4	92·1	30·95	−26	85	W.	2	0
	23	58·4	92·1	·97	−30	85	Calm.	0	0
	24	58·4	92·1	·78	−15	87	Calm.	0	10
	25	58 4	92·1	·90	−22	86	Calm.	0	0
	26	58·4	92·1	·91	−30	85	Calm.	0	0
	27	53·4	92·1	·87	−27	86	W.	2	10
	28	53·3	83·8	·93	−28	82	Calm.	0	0
	29	56·8	60·6	·93	− 1	74	W.	11	0
	30	56·8	60·6	·96	− 3	72	W.	2	0
	31	58·4	92·1	31·08	−21	87	Calm.	0	0
1878.									
Jan.	1	57·6	76·3	·01	−26	86	Calm.	0	0
	2	53·8	48·6	·02	− 6	82	S.	2	0
	3	53·8	48·6	·01	− 1	80	S.S.W.	2	4
	4	41·3	69·3	·09	−10	92	Calm.	0	0
	5	41·3	69·3	·02	− 4	87	Calm.	0	0
	6	58·4	92·1	·06	−28	85	Calm.	0	0
	7	58·4	92·1	·25	−30	85	Calm.	0	0
	8	58·4	92·1	·15	−28	86	Calm.	0	0
	9	58·4	92·1	·20	−33	85	Calm.	0	0
	10	58·4	92·1	30·98	−21	86	Calm.	0	0
	11	58·4	92·1	·93	−20	86	Calm.	0	0
	12	53·3	83·8	·86	−17	85	Calm.	0	0
	13	53·3	83·8	·77	− 8	89	Calm.	0	5
	14	58·4	92·1	·98	−13	86	Calm.	0	0
	15	58·4	92·1	·85	− 5	78	E.	2	0
	16	40·0	116·5	·77	+10	24	N.W.	40	0
	17	40·0	116·5	·68	+12	34	S.W.	22	0
	18	40·0	116·5	·73	+20	30	Calm.	0	0
	19	41·3	69·3	·84	+31	92	Calm.	0	0
	20	58·4	92·1	·74	− 5	82	N.W.	2	5
	21	53·8	48·6	·44	−11	68	S.S.E.	2	0

Northern Russia. A small area of low pressure which prevailed over Southwestern Europe, and a low area which apparently prevailed near the northern boundary of Asia may have contributed to this effect. For the four following days, the phenomena remained nearly the same, but the pressure near the center of the high area increased, and on the 6th the isobar of 30 inches included almost the whole of Asia, extending into the Pacific Ocean on the east, and it also included a large part of Europe. On the 7th there was a slight diminution of pressure which continued during the three following days, and this was apparently the effect of a low area in Northern Asia which drew off the air from the Northern side of the high area, and the center of the high area was thereby carried southward. On the 10th the pressure on the north side was restored, and the center of the high area moved northward, but the barometer did not commence rising until the following day. On the 11th the barometer began to rise, and now the small low area which had prevailed over Southern Europe since Dec. 2d was obliterated by the advance of a high area from the Atlantic Ocean. On the 12th the barometer rose somewhat higher; at most places the wind had subsided almost to a calm, and the air was generally less humid. On the 13th the rise in the barometer was more decided, and now a great change of temperature which for several days had been steadily advancing from the eastward, had reached the center of high pressure.

On the 14th the isobar 31·0 inches included an area about 1400 miles in length and 800 in breadth, and the pressure attained its maximum between the 16th and 17th. On the 19th the isobar 31·0 inches apparently included an area 3400 miles in length, and 1450 miles in breadth. Throughout the central portions of this high area, the air was dry, the wind subsided almost to a calm, and the sky was generally cloudless. After the 17th the barometer began to fall, the temperature rose somewhat, the humidity of the air increased, and there was some cloudiness, but the clouds were reported *light*. This decline of pressure may have been due to the fact that the outward movement of the air from the high area had become greater than the supply from the low areas before named, two of which had now become extinct. After the 20th the low area which had prevailed over the Atlantic Ocean advanced eastward, and on the 14th the isobar 29·0 inches included the whole of Norway, by which means the pressure throughout Europe and Western Asia was greatly reduced. At the same time there was some increase of temperature, but the rise of the thermometer indicated by Table V on the 20th and 21st, was due mainly to a change of position of the high center. The thermometer at Barnaul still continued 30 degrees below zero of Fahrenheit.

After the 24th the low area over Norway was diverted westward, perhaps by the warmer and more humid air upon that side, and after the 27th the pressure over Asia began to increase, and reached 31·0 inches on the 31st, at which time the conditions were similar to what they had been on the 14th, but the cold at the center of the high area was less intense. The region of greatest cold was near the center of Asia, but up to Jan. 5th the center of the high area was in Eastern Europe or in Western Asia. The high area was apparently attracted westward by a second high area in the neighborhood of Spain which coalesced with the Asiatic area on the 3d. On the 4th a considerable area of low pressure, which on the preceding day had prevailed near the coast of Norway, pushed farther eastward, by which means the pressure in Northern Europe was diminished and the center of high pressure moved eastward. It now came into the region where a very low temperature had been prevailing since the beginning of December. Simultaneously with the fall in temperature, the pressure at the center increased and continued thus through the 9th. On the 10th the barometer fell below 31·0 inches and for the next 10 days continued with some fluctuations to decline until it fell below 30·5 inches. The most important cause for this decline, as far as can be learned from the International maps, was the eastward progress of the low area in Europe already mentioned. This low area drew off the air from the western side of the Asiatic high area, and after the 9th the high area was not built up on its eastern side as fast as it was reduced on its western side. On the 16th and 17th a low area from the Pacific Ocean crowded the high area on its northeast side, in consequence of which the center of the high area moved southward. The rise of the thermometer shown by Table V, from the 16th to the 19th was the result of this southward movement of the center of high pressure. At Nertchinsk the thermometer still remained below zero of Fahrenheit. On the 19th the Pacific low area was filled up by the air which pressed in from the north, and the result was a slight increase of the high area over Central Asia. This increase was however but temporary, for on the 21st the storm which had long prevailed in Europe gained a considerable increase of intensity while a low area of moderate extent pushed northward from the Persian Gulf, and by the union of these two low areas the high area over Asia was completely broken up, and on the 22d the highest pressure reported at any of the Russian stations was 30·3 inches.

The history of this high area which for 50 successive days covered a large portion of Europasia, and which obtained a maximum greater than has ever been known at any other time in any part of the world, ought to furnish a basis for some

important conclusions. If it should be asked what is the cause of areas of high pressure, the answer is plain, they are the *necessary* concomitants of areas of low pressure. If at any place of the earth's surface the barometer sinks below its mean height, it must rise above its mean height at some other place. If we find an area of low pressure of vast extent, we know that there must be a corresponding area of high pressure in some other part of the world. For the entire globe, the total amount of air which at any instant is elevated above the mean level surface must be exactly equal to the total amount which in other regions is abstracted from beneath the mean level surface. Areas of high pressure are therefore built up by air which comes from areas of low pressure. We also know that within an area of low pressure at the surface of the earth, there is a general movement of the air *inward;* that near the central portion of this area the air ascends and flows off to other portions of the globe. Also within an area of high pressure at the surface of the earth, there is a general movement of the air *outward;* and since high areas often continue many days and sometimes many weeks, there must be a fresh accession of air at the top to supply the place of the air which is drawn off by the outward movement near the surface of the earth. The air which ascends from an area of low pressure goes therefore to maintain the descending movement within an area of high pressure. This deduction seems so obvious as scarcely to require confirmation from direct observations. It has however been abundantly confirmed by an extensive series of observations on the movement of cirrus clouds made in 1875 and '76 under the direction of Dr. Hildebrandsson. By these observations it has been shown that the air which ascends from an area of low pressure, after reaching an elevation corresponding to the usual height of the cirrus clouds, recedes from the center of the low area, and moves toward an area of high pressure.

When we attempt to apply this general principle to a particular case we are frequently in doubt as to the particular low area from which a given high area draws its supply of air. In the observations collected by Dr. Hildebrandsson, when a low area prevailed over the Atlantic Ocean and a high area over Eastern Europe, the cirrus clouds generally moved toward the area of high pressure on the east side; but when a low area prevailed over Eastern Europe with a high area over the Atlantic Ocean the cirrus clouds generally moved toward the area of high pressure on the west side. It is noticeable that the period of greatest barometric pressure over Europasia corresponds with the period of least pressure over the Atlantic Ocean. There does not therefore seem to be any room for doubt that the high areas of Europasia derive their chief supply of air from the low areas which prevail over the Atlantic Ocean.

If we enquire for the cause of the low temperature which generally attends areas of high pressure, I think we must admit that the low temperature is in part the cause and in part the effect of the high pressure. A low temperature increases the density of the air, and the height of a given weight of air is thereby diminished. Its pressure is not however thereby increased, but the void left in the upper regions of the atmosphere must be filled by air flowing in from neighboring regions, and the pressure over the cold area is thus increased. The reduced temperature becomes indirectly a cause of increased pressure. This high pressure accompanied by extreme cold generally results in a calm and dry atmosphere free from clouds. The heat of the earth's surface is now rapidly dissipated by radiation, and thus the high pressure becomes a source of increased cold. High pressure and low temperature reënforce each other, and they are almost invariably associated, particularly in the extremely high pressures which occur during the colder months of the year.

The long duration of areas of high pressure over Europasia appears to be due to the favorable conditions for the formation of such areas which prevail in this part of the world during the winter months. During this period, areas of low pressure of extreme violence prevail almost uninterruptedly over the Atlantic Ocean, and the air which here ascends moves eastward and settles down over Europasia. This is a vast continent, the central portions of which are removed to a great distance from any large body of water. Here the sources of atmospheric disturbances are few—the air is generally tranquil and without much cloudiness—the heat of the earth is rapidly wasted by radiation—and the low temperature reënforces the high pressure. Thus during the winter months, high pressure over Asia becomes as habitual as low pressure over the Atlantic Ocean.

During each of the winters from 1878 to 1884 the areas of high pressure over Europasia exhibited characteristics similar to those we have found for the winter of 1877–8. In the winter of 1878–9 from Dec. 18, 1878 to Feb. 11, 1879, a period of 56 days, an area of high pressure prevailed over a large portion of Europasia, and during this period the pressure at the center at no time sunk below 30·5 inches. At three different times during this period the barometer rose above 31·0 inches and it attained a maximum of 31·26 inches. During the winter of 1879–80 an area of high pressure prevailed over Europasia from Jan. 5th to March 4th, 1880, a period of 60 days without at any time sinking below 30·5 inches; and on eight different days the pressure was as high as 31·0 inches, the maximum being 31·17 inches. During the winter of 1881–2 an area of high pressure prevailed over some part of Europasia from Nov.

27, 1881 to Feb. 25, 1882, a period of 91 days, during which time the barometer at some one of the stations was observed as high as 30·5 inches. On six days the barometer rose above 31·0 inches and it attained a maximum of 31·2 inches.

In reviewing the history of these seven years we must conclude that the areas of high pressure which are so prevalent over Europasia during the winter months show no decided progressive movement in any fixed direction. They often remain nearly stationary for weeks in succession, with only such apparent motion as is due to a slight decline in some places and a slight reënforcement in other places, resulting perhaps from local causes, or from some change in the circulation of the upper strata of the atmosphere.

We also see that a pressure of at least 30·5 inches is almost uninterrupted over some portion of Europasia during the winter months, and the interruptions which occasionally occur are due to areas of low pressure which push southward from the higher latitudes. The rarity of this phenomenon, and the smallness of the depression when it does occur, illustrate the difficulty which an area of low pressure experiences in penetrating a huge mass of very cold air.

The accompanying plate, derived from the International observations, will give a more distinct idea of the relation of areas of high and low pressure, and will show the magnitude which these areas sometimes attain. The plate gives the isobars for Dec. 15, 1882, and shows a high area covering nearly the whole of Europe and Asia and extending somewhat over the Pacific Ocean. Another high area covers nearly the whole of North America; an area of low pressure, with its isobars very much elongated, stretches entirely across the Atlantic Ocean, overlapping portions of Europe and America; and another area of low pressure covers a large part of the North Pacific Ocean. Two high areas, combined with two low areas, make the entire circuit of the northern hemisphere near the parallel of 50°. A third high area, of moderate elevation, is found over the southern part of the North Atlantic, and there is a fourth high area of small extent over the Pacific Ocean near the coast of California. This map represents in an exaggerated form the average distribution of pressure during the winter months, viz: high pressure over the continents and low pressure over the oceans.

It is very rare that so small a number of areas of high and low pressure complete the circuit of the northern hemisphere. Generally the areas are much more numerous and of smaller dimensions; the areas are of very unequal size and are combined in very irregular positions; but during the colder months of the year, low areas are most prevalent over the Atlantic and

Pacific oceans; a high area generally prevails over Europasia, frequently showing more than one center of maximum pressure, and a moderately high area generally prevails over some part of North America, but it is not as persistent as the high area over Asia.

The facts stated in this paper clearly show that the movement of areas of high pressure depends upon very different causes from that of areas of low pressure. Areas of low pressure seem to be endowed with a power of locomotion which resides within themselves. The heat liberated in the condensation of vapor develops a power which draws in the surrounding air, and this motion, combined with the movement which results from the general system of atmospheric circulation, causes a rapid displacement of the low center. Areas of high pressure exhibit no such power. Their low temperature creates a tendency to crowd toward a warmer region; and this tendency is obscurely seen in the high areas of Europe and Asia. It is more distinctly seen in the high areas of the United States, probably on account of the proximity of a much higher temperature, viz: the Gulf of Mexico on the south, and the Atlantic Ocean with the Gulf Stream on the east. Aside from this cause, the movement of areas of high pressure seems to depend entirely upon external forces. A neighboring area of low pressure may draw off the air from one side, and thereby cause a displacement of the center of maximum pressure; or the high area may be reënforced at the top in such a manner as to cause a rapid movement of the center of maximum pressure, in a direction and with a velocity which are apparently subject to no law.

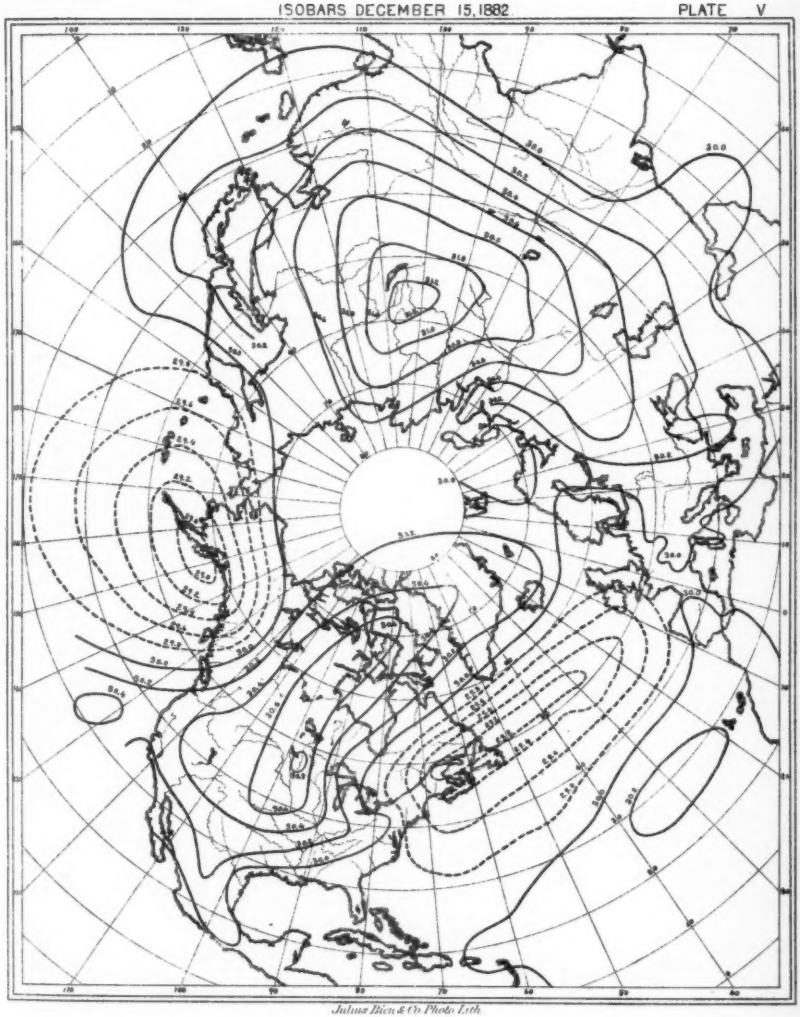
ART. XXIX.—*The Faults of Southwest Virginia;* by JOHN J. STEVENSON, Professor in University of the City of New York.

THE existence of great faults in southwest Virginia was made known in 1836 by Professor Wm. B. Rogers, three principal faults being shown on the long cross-section appended to his "Reconnaissance."* The existence of the Saltville and New Garden faults is asserted in a paper on Thermal Springs by the same author and in a long memoir on the structure of the Appalachian Chain by Professors W. B. and H. D. Rogers.† At a much later date, Professor J. P. Lesley ran several lines across portions of the faulted area on both sides of New River

* Report of the Geological Reconnaissance of the State of Virginia, 1836.

† These papers are contained in the volume of the Transactions of the Association of American Geologists and Naturalists, 1840–42.

ISOBARS DECEMBER 15, 1882 PLATE V



Julius Bien & Co Photo Lith

and added greatly to the knowledge of the general structure,* of which he first appears to have had a clear conception. Professor Safford's map of Tennessee shows the extent of the faults in that State. The writer has made a reconnaissance of the faulted region in Virginia from the Tennessee line to almost twenty miles beyond New River, a distance of 150 miles, and has given the results in several memoirs read before the American Philosophical Society.† As these last are independent, information respecting the several faults is broken in such a way that a summary statement is necessary to render it available. If more of detail should be needed, the reader is referred to the memoirs cited.

The "Great Valley" follows the northerly or northwesterly foot of the Blue Ridge from New England to Alabama and, except where broken by faults, is underlaid by Lower Silurian and Cambrian rocks. In New York, Pennsylvania and Maryland, it is bounded on the northerly side by anticlinals and synclinals carrying the newer rocks so that within a little distance one is in the Upper Devonian. The conditions are simple, there being no faults of great longitudinal extent cutting off the valley on that side. The only faults lie at a considerable distance beyond the valley and, though of much interest, are utterly insignificant in comparison with those found farther south.

At no great distance southward in Virginia, strips of Lower Silurian are shown beyond the line of the "Great Valley." These are more numerous near New River and become wider thence to the Tennessee line; while near and beyond the same river the valley itself is broken by patches of Upper Silurian, Devonian and even Lower Carboniferous rocks. These great changes are due to faults as remarkable for their longitudinal as for their vertical extent.

The greatest width of the faulted area in southwest Virginia is about forty miles, measured along a line passing through Wythe, Giles and Tazewell Counties of Virginia. The faults, separated by varying intervals, show Knox limestone on the southerly or upthrow side, while the beds on the northerly or downthrow side may belong anywhere from Lower Silurian to Upper Carboniferous. Thus the region is broken into a series of alternating "rich" and "poor" valleys, underlaid in the former by Lower Silurian limestones and in the latter by Upper Silurian and Devonian shales. The sections shown by

* Professor Lesley's papers were read before the American Philosophical Society on May 16th, 1862, and on April 21st, 1871.

† The dates of these papers are August 20th, 1880, January 21st, 1881, October 7th, 1881, November 21st, 1884, and one not yet read before the Society.

the blocks held between the faults vary much in length, the most extended being that between the Copper Creek and Saltville faults, where the column reaches from the bottom of the Knox calcareous rocks to the top of the Umbral, possibly in some places to the Coal Measures.

The blocks between the faults are not always monoclinals, as might be inferred from a hasty perusal of some papers presented prior to those of the writer; far from it. Where the blocks are broad, seven or eight miles, groups of anticlinals occur, canoe-shaped and overlapping, thus reproducing the features so characteristic of Upper and Lower Silurian areas in Central Pennsylvania. But these folds are not parallel to the faults and any relationship appearing to exist between the faults and such folds is evidently fortuitous.

Three faults entering Virginia from Tennessee, termed by the writer, the Poor Valley, the Wallen's Ridge and the Pattonsville, and having a vertical extent of 2400, 2800 and 500 feet respectively, disappear within a few miles, being simply fissures on the southeasterly side of a bold anticlinal, that of Powell-Stone Mountain, which also disappears within a short distance. The important, persistent faults are—

The Clinch Group, the Copper Creek, the Saltville, the Walker Mountain; beside which are the short faults of Draper and Price Mountains in the valley, with the cross-faults, Max Meadows and Pulaski, extending from the Draper Mountain fault toward that of Walker Mountain.

The *Clinch Group* of faults includes the Clinch Uplift and Abb's Valley fault of Professor Lesley's 1871 memoir; as the writer ran some lines between those of Professor Lesley, he has been enabled to elaborate the group somewhat and to discover a more complicated structure than was at first supposed. The group consists of—

a. The Hunter Valley fault or Clinch Uplift; *b.* The New Garden fault; *c.* The Stony Ridge fault; *d.* The Abb's Valley fault.

The Clinch Uplift enters Scott County, Va., from Tennessee, continues through that county into Russell without interruption; but midway in the latter county, after bending northward, it gives off a cross fault and holds its new course into Buchanan County where it is soon lost. The New Garden fault begins in Russell County not far from the line of Scott and almost accurately in the place where the former fault ought to have been found had its course been unchanged; it is joined by the cross fault from the Clinch Uplift and it continues through Russell and Tazewell Counties of Virginia into Mercer County of West Virginia, where it follows the northerly foot of East River Mountain to certainly twenty-five miles beyond

New River. The Stony Ridge fault begins in Russell County and continues thence through Tazewell into Mercer County of West Virginia. The Abb's Valley begins in Tazewell County and extends into Mercer County. These two faults do not appear to reach New River, but of this the writer may not speak positively as he has not crossed their place near the river. The intervals between these faults increases eastwardly.

The *Copper Creek* fault enters from Tennessee, passes through Scott County and within a few miles in Russell County disappears in the Elk Garden anticlinal, a fold with double or triple crest, which is followed easily through Russell and Tazewell Counties into Bland; but soon after entering the last county a double fault, the Winonah, arises from the anticlinal, which, at a few miles farther, gives off from its northerly side a second, that of Buckhorn Mountain. These two faults cross the New River and enter Craig County, but they evidently disappear a little way beyond, as they do not appear there in Rogers's cross-section. Where the Buckhorn fault begins, the interval to the other is only a few rods, but at New River it is almost two miles. The Winonah, like the Copper Creek fault, is in Knox, but it holds a vertical wall of white Medina in the crevice. It evidently gives off a similar branch beyond New River, for there two lines of white Medina appear in the Knox limestones.

The *Saltville* fault, the *North Holston* fault of Lesley's 1871 memoir, is, so far as the writer has been able to determine, a continuous fracture from Tennessee to thirty miles beyond New River. How much farther it extends, the writer has not yet ascertained. It is of especial interest in that its course exhibits total indifference to that of the anticlinals and to the strike of the rocks. It shows no material variation in the extent of its throw.

The fault of *Walker Mountain* enters Washington County from Tennessee as a throw in the Knox beds, but soon after entering Smyth County the throw becomes stronger and before entering Wythe County, Umbral shales are shown on the downthrow side. Thence to twenty miles beyond New River the fault remains the same. How much farther it extends was not ascertained, but like the Saltville it gives promise of many miles. One of these two is, no doubt, the "great fault" so often spoken of as following the northerly or northwesterly side of the valley.

The *Draper* Mountain fault is a short fracture in Wythe and Pulaski Counties, which brings up the Potsdam as a rugged mountain in the heart of the valley. Two cross-faults pass rom it, the Max Meadows in a westward direction and the Pulaski in a northwestward direction, toward the Walker

Mountain fault; so that in the very heart of the "Great Valley" there is a block of Upper Silurian, Devonian and Lower Carboniferous with Lower Silurian on two sides, Cambrian on the third and Lower Carboniferous on the fourth.

A curious double fault, that of Price Mountain in Montgomery County, brings up a short anticlinal ridge of Lower Carboniferous midway in the valley. This V-shaped fault is short and its branches are separated by an interval of not more than three miles and a half at the widest place.

The faults do not follow straight lines and their courses show much variation. The intervals show equal variation.

As has been said already the vertical extent of a fault is not the same along the whole line. It was observed that the faults where followed out proved to be merely cracked anticlinals; the most notable illustration being found in the Copper Creek fault, which disappears in the Elk Garden anticlinal, only to reappear after a distance of seventy miles in the Winonah and Buckhorn faults, which in their turn disappear in an anticlinal. The Max Meadows, Draper Mountain, Abb's Valley faults and the three small faults of Lee and Scott Counties illustrate the matter almost equally well. Such being the origin of the fault, variation in the vertical extent must be looked for.

But the strength of the throw may be the same for a long distance while the apparent strength may be very different. The development of anticlinals on one side or the other, anticlinals belonging to a time prior to the formation of the faults, may cause the appearance of successive groups on one side. An admirable illustration is found in the Saltville fault, which has Knox limestone on the upthrow side throughout the whole distance examined, while on the downthrow side one finds the whole series from the Knox limestone to the Umbral shales, possibly to the Coal-measures. But the extent of the throw is the same throughout, the variation being due to the presence of anticlinals crossed by the fault.

The Hunter Valley fault or Clinch uplift illustrates well the variation in strength of the throw. Where it enters from Tennessee it shows Knox on the upthrow and Clinton on the downthrow side; but within a few miles Hamilton is on the downthrow, while within ten miles farther, Lower Coal-measures (Quinnimont) are in the fault on the downthrow side. The upthrow diminishes in Russell County beyond the origin of the New Garden fault so that Middle Coal-measures are in contact first with Devonian and then with Lower Coal-measures. The Walker Mountain fault illustrates the same thing equally well, for though it enters as a fault in the Knox the downthrow gradually increases until in Wythe County the whole series to the top of the Umbral is seen.

The extent of the faults, both vertical and longitudinal, is as follows:

	Vertical.	Longitudinal in Virginia.
Poor Valley	2,400′ to 0′	40 miles.
Wallen's Ridge	2,800′ to 0′	25 "
Pattonsville	500′ to 0′	20 "
Clinch Group—		
a. Hunter Valley	8,500′ to 0′	65+ "
b. New Garden	7,500′ to 0′	102+ "
c. Stony Ridge	2,300′ to 0′	50+ "
d. Abb's Valley	1,700′ to 0′	40+ "
Copper Creek, etc.	3,000′ to 0′	45 "
Saltville	10,000′ to 500′	130+ "
Walker Mountain	10,000′ to 1,000′	130+ "
Max Meadows	9,800′	20 "
Pulaski	9,600′	8 "
Draper Mountain	12,500′ to 0′	20 "
Price Mountain	10,000′	10+ "

The conditions in the immediate vicinity of the apparent fault lines are not easily ascertained, for ordinarily the line of contact and the area to a considerable distance on each side are covered by rubbish. More than that: the thrust has been sufficient to shove the upthrown beds to a considerable distance over on the downthrown beds as is shown by the Hunter Valley fault on Big Stony Creek in Scott County, so that the place of the fault is necessarily somewhat obscure. That the faults are practically cracked anticlinals, however, is sufficiently evident from their origin and disappearance; but traces of the anticlinal structure are not wanting along the faulted lines. Thus the great Clinch or Hunter Valley fault shows, near the Tennessee line, Clinton and Knox in contact but each dipping from the fault. A similar structure was seen thirty miles farther eastward, where Lower Carboniferous and Devonian are upturned on the northerly side of the fracture; while still farther east the Lower Coal-measures (Quinnimont) are shown on the northerly side dipping away from the fault at sixty to seventy degrees, with the Knox beds on the other side also dipping away from the fault but at a less rate. But the conditions vary, and at several localities along this fault the dip on the downthrow side is toward the fault, the thrust evidently having been sufficient to carry the upthrown rocks over the line to a considerable distance. This is apparently the condition along the Walker Mountain fault everywhere within the area examined; for the conformability is so close that the existence of a fault would not be suspected by one depending only on the local stratigraphy.

Rocks in the immediate vicinity of the apparent fault line—

where the upthrown and downthrown rocks are in contact—frequently show no signs of disturbance other than abrupt dip; but the proof of disturbance is much more distinct on the upthrow side at a distance of somewhat more than half a mile and beyond; while even on the downthrow side the dip may be greater at some distance than it is at the fault line itself. Where New River crosses the Walker Mountain fault, the dip on the downthrow is fourteen or fifteen degrees, but at barely half a mile farther down the stream, the dip is fifty-five degrees; yet within fifteen miles toward the east, the conditions are altogether reversed, the shales dipping very abruptly near the fault, while, at about one-fourth of a mile away, the sandstones are dipping at but twenty-five degrees.

But on the upthrow side the disturbance in any case is not confined to mere variations in rate of dip; the crushing is proved by numerous narrow, crowded, abrupt folds, beginning at half a mile or so from the fault and continuing for even a mile or more. These are especially noteworthy near the faults of the Clinch Group, but they are shown in some places near the Walker Mountain fault. The crushing at several localities near Clinch River is excessive and at one locality the shales are folded as closely as micaceous shales on Manhattan island, but they show no evidence of metamorphism.

That the faults are closely related in several instances to anticlinals has been stated already more than once; but a system of folds still remains, though in fragments, with which the faults have but a fortuitous connection. The conditions cannot be exhibited here without the aid of somewhat complicated diagrams; but the colored maps accompanying the writer's memoirs already cited make the matter sufficiently clear.

The Saltville fault, best of all in Virginia, shows the conditions, for it cuts off several folds existing in the interval between it and the Copper Creek fault at the north, a space ten to twelve miles wide. The first fold at the west, the "Great Garden" axis of W. B. Rogers, is an inverted canoe, about eighty miles long and attaining its maximum in Burk's Garden of Tazewell County. As the fault does not follow the strike but simply cuts along the side of the canoe, it is clear enough that the section on the northerly or downthrow side must show noteworthy variations as the line approaches or leaves the higher, wider portion of the canoe, while no change is shown on the opposite or upthrow side. And this is the condition; for while the Knox limestone is on the upthrow side throughout, changes enough appear on the other side. Thus in Washington County opposite Mendota, the width of Lower Carboniferous is nearly four miles, in which a magnificent section of Umbral and Vespertine is shown. But at the edge of

Bland and Smyth Counties, where the Garden fold is greatest, the strip of Lower Carboniferous is barely half a mile wide and the presence of both divisions is due only to a remarkable decrease in thickness of the Umbral. As the anticlinal diminishes, the width of Lower Carboniferous increases; but the higher rocks are not reached, for within fifteen miles in Bland County, the fault cuts off the Kimberling anticlinal near its origin.

This fold rapidly increases in height and under its influence Lower Carboniferous rocks soon disappear from the downthrow side and the Knox is in contact with Lower Devonian near the line between Bland and Giles Counties. A third anticlinal, the Sinking Creek, is cut by the fault a little farther on; and as it increases in height, the Knox is brought into contact with the successive groups of the Upper Silurian, with the Hudson, the Trenton, and finally with the upper Knox before New River has been reached; while beyond that river, the diminution of the fold permits the presence of Trenton, Hudson, and, before the eastern limit of Giles County has been reached, of Medina on the northerly side of the fault.

The axes of these anticlinals are approximately parallel and make a considerable angle with the fault.

A similar condition exists in the curious block within the Great Valley enclosed by the Walker Mountain, Draper Mountain, Max Meadows and Pulaski faults. The Walker Mountain fault cuts off, in succession, Lower Silurian, Upper Silurian and Devonian on the upthrow side, while on the downthrow side Umbral shales are shown continuously. Within the block is an anticlinal which apparently is in no way connected with any of the folds observed in the Knox beds outside of the block.

The Great Cove fault of Fulton County, Pennsylvania, as described by the writer* shows, as far as it goes, equally well with the Saltville, this indifference to the course of the pre-existing folds. The Cove anticlinal, like the Garden axis, is an inverted canoe with its eroded cove surrounded by a wall of Medina. The fault, which holds a jagged wall of Medina in the crevice, makes but a small angle with the axis of the anti-

*Second Geol. Surv. of Penn. Rep. on Bedford and Fulton Counties, p. 55. This reference affords an opportunity of satisfying the "long-felt want" of some acquaintances, who are at a loss to reconcile my maps of these counties as appended to the report with the maps of the same counties as given in the Geological Atlas of Pennsylvania. The maps *cannot* be reconciled. Those appended to the geological report on the counties are by the writer, except in so far as they refer to the Broad Top region, and, except in so far as they refer to that region, they are fairly good. The maps in the Geological Atlas, though credited to me, were not made by me in any sense whatever; they were printed three years or more before I even thought of doing any work in Bedford and Fulton Counties.

clinal, but sufficient for curious variations, as may be seen by consulting the writer's map of Fulton County.

The facts that have been given lead the writer to the conclusion that the faults are of later date than the system of folds and that they may have been produced at a time possibly as late as the era of Mesozoic disturbance marked by dikes throughout the Triassic area of the Atlantic border.

ART. XXX.—*On Taconic Rocks and Stratigraphy, with a Geological Map of the Taconic Regions;* by JAMES D. DANA.

[Continued from vol. xxix, p. 443, March, 1885.]

PART II.—THE MIDDLE AND NORTHERN PART.

THIS part of my memoir, with the map illustrating it, covers the region from the southern boundary of Great Barrington to the northern limit of Berkshire, together with the towns of Pownal and Bennington in southern Vermont, and the eastern border of New York for a breadth of about three miles. The map, as with the former part, has only the limestone areas colored. Over the rest the kinds of rocks are indicated by letters. The scale of the map is half an inch to the mile.*

The following are the subdivisions adopted beyond in the discussion of the subject.

I. General facts relating to the geographical distribution of the limestone and other rocks.
II. The limestone and the overlying Taconic strata.
III. The underlying quartzyte formation.
IV. General conclusions.

1. *General facts relating to the geographical distribution of the limestone and other rocks.*

1. *Williamstown the birthplace of the Taconic system.*—The map accompanying this paper contains, in its northwestern part, the town of Williamstown; and there in connection with Williams College were Prof. Amos Eaton in 1817 (for a single season), Prof. Chester Dewey from 1817 to 1827, and Prof. Ebenezer Emmons in 1833 and for many years afterward. There Dewey investigated and was the first to investigate the Taconic rocks, the first to give the term "Taconic," as applied to the ridges, its present form (in 1819); the first to publish a geological map of the region.† As the history at this point has been writ-

* The map will be inserted in the following number.

† For his papers see this Journal, vols. i (1819), ii, (1820), viii (1824); the last contains his geological map of western Berkshire.

ten incorrectly, I add here that Eaton gives credit for what he knows of the region to Dewey.*

But Prof. Dewey's work was only a beginning. Prof. Emmons took up the investigation thus initiated and made thorough work of it; and finally, adding to his study of the Williamstown region that of western Berkshire and Eastern New York, gathered the facts upon which he based the Taconic system, and his opinions as to the contrast between them and the oldest Paleozoic strata of central and northern New York.

2. *General features.*—The general trend of the chief Taconic Range and of the Taconic belt of rocks is very nearly that of the western New England boundary—or about N. 15° E. along the limit of Massachusetts, and about N. 5° E. along that of Vermont.

The topography of the part under consideration is similar to that of the more southern section already described. The limestone is intersected from north to south by ridges of schist and the other overlying rocks, and the most of these schist ridges stand isolated within the limestone area, or run out into the area from the larger ridges like peninsulas. Few limestone areas on the map are wholly enclosed by the schist, and thus detached from the main mass.

3. *The old subdivision of the Taconic limestone into an eastern and western belt not valid.*—The distinction of two ranges or belts of limestone, an *eastern*, east of the main Taconic Range, and a *western*, west of it, was first recognized by Dewey, who named them, in the language of the day, the *Primitive* and the *Transition*, the latter name being given to the western, because the rock was but feebly crystalline. The subdivision, as has been before explained, is a fundamental feature of the "Taconic system." The former of the two limestones is distinguished by Emmons as the Stockbridge limestone—a name adopted by Prof. Edward Hitchcock for the Berkshire limestone, while for the Eastern Vermont belt he used the term Eolian limestone.

a. The *eastern* or Stockbridge limestone belt is continuous from near Towner's (on the Harlem R. R., 45 miles from New York city), and also by a more eastern branch, from New Fairfield, Connecticut, nearly in the latitude of Towner's, to Clarksburg, on the northern border of Berkshire, a distance of about 95 miles. In North Adams, the town next south of Clarksburg, the belt approaches on its west side the Williamstown limestone within less than a mile, but nowhere has a direct connection with it at surface. From Williamstown the limestone enters Vermont and (as the Vermont geological map indicates),

* Index to the Geology of the United States, 1820, in which he acknowledges the "assistance, for two or three years, of that able and accurate naturalist, Prof. Dewey, of Williams College."

stretches on uninterruptedly to Weybridge, beyond Middlebury, making within the limits of Vermont, another 95 miles.

The *western* limestone, or that west of the main Taconic Range, is, in the first place, not a continuous belt; and, secondly, two of its long pieces west of Massachusetts are nothing but branches from the eastern limestone, being directly continuous with it, instead of distinct lines. It includes in the region here considered, three parts, a northern, a middle and a southern, all in eastern New York. The *northern* is confined to the towns of Hoosic and Petersburgh. The *middle* commences five miles south of the northern, in northern Berlin, and extends about 25 miles through Stephentown and New Lebanon to the southern part of the town of Canaan, N. Y. The *southern* has its north end in Hillsdale, N. Y., 8 to 9 miles south of Canaan; and thence it continues southward through Copake into Ancram (11 to 12 miles), where it divides into two branches, each of which, except for a break of 4 to 5 miles, extends southwestward to the Hudson, reaching it near Poughkeepsie and Fishkill—a distance in all of 50 to 60 miles. Thus there is no one independent western belt.

The two pieces that are only branches from the great Vermont eastern limestone are (1) the northern and (2) the middle; and (3) the southern makes a very near approach to a junction with the Massachusetts eastern limestone.

In further explanation I state that the northern area, or that of Petersburg and Hoosic, passes bodily from Hoosic into northern Bennington where it joins the Vermont eastern belt, or becomes identified with it. This same northern portion *nearly* makes another junction with the eastern belt, along the Hoosic valley in northern Pownal; but about two-thirds of a mile of slate intervene.

The middle one of the western areas, or that which extends from Berlin southward to Canaan, stretches northeastward from Stephentown through Hancock, Mass., to Williamstown; or, viewed from the other direction, the Williamstown limestone, which is a southern part of the Vermont eastern (or Eolian) limestone, continues on southwestward (as Hitchcock first showed) through Hancock to Stephentown and Canaan; so that this western limestone is the southern termination of the eastern. The distance from northern Williamstown to its extremity in Canaan is about 35 miles, and hence the Vermont eastern belt, or Eolian, with this its continuation, is 130 miles long.

The approach to a junction between the middle western and the Massachusetts eastern limestone takes place at the southern end in Canaan, where a long tongue runs out eastward in the open valley which there crosses the Taconic Range and makes

a nearly level pathway through the mountains for the Boston and Albany railroad. The tongue-shaped prolongation of the limestone area extends eastward through the range, but half a mile of schist intervenes between it and the limestone area of West Stockbridge and Richmond.

The southern of the western areas is the only one that makes no complete junction with the eastern belt; but it approaches it, as explained in the former part of this paper, at the low and broad gap in the Taconic range, between Salisbury, Ct., and Millerton, N. Y.

The deep gaps or open valleys that cross the range are deep openings through the Taconic schists, and hence the outcrop of the limestone through, or nearly through, the gaps.

These facts touch a fundamental point in the Taconic system, for they show that the difference in grade of the metamorphism between the limestone areas of the eastern and western sides of the Taconic range—a point of difference dwelt upon by Emmons—has no stratigraphical importance. The rocks are one in mass beyond possible question. We thus take one member out of the Taconic system by showing its continuity with one of the others. We find, in other words, that the great limestone of the Taconic series is stratigraphically one single formation. This statement does not imply that the limestone is all of one period; but that it is one in mass and general conformability.

This conclusion is fortified by the proof already presented of a synclinal structure in Mt. Washington, that is, of the passing of the limestone from east to west underneath the mountain; and also by that of another synclinal, as long since pointed out by Emmons, and also afterward by Hitchcock, in the Greylock mass, by which the Williamstown and Adams limestones —the Eolian and Stockbridge—join one another. Additional evidence on the latter and related points will be found beyond.

4. *Irregularities in the courses of the belts of the Taconic series that appear to be, in part at least, due to earlier topographical conditions.*—Two abrupt east-and-west shifts in the course of the Taconic belt are indicated on the map.

a. The most extensive of these abrupt changes of line is in the northern part of Berkshire. Here the eastern or Stockbridge limestone, as above stated, stops off abruptly in the town of Clarksburgh, and begins again to the westward in Williamstown. This change in geographical position amounts to four or four and a half miles, measuring from the eastern limits of the two limestone areas.

The quartzyte is shifted to the same extent. To the south, through Cheshire, East Lenox and beyond, the line of quartzyte outcrops is in general four to five miles east of the

line of the quartzyte range of Bald Mountain on the boundary between Clarksburg and Williamstown; and its continuation northward. The shift is also exhibited in the Archæan rocks. For directly north of the Stockbridge limestone of Clarksburg there is an undoubted Archæan area—that of the "Stamford granite"—of the Vermont survey,* and this Archæan area stands against the eastern side of the quartzyte range of Bald Mountain. So again to the south, in Berkshire, the quartzyte has in several places similar hornblendic Archæan rocks not far east of the outcrop of quartzyte. Thus the shift is marked in the three great formations of the country.

b. Another westward shift, or apparent shift, occurs in Southern Vermont, in the latitude of Bennington, and is about a mile in extent. The limestone limit on the *east* of the village of Bennington with the quartzyte range west of it shows, on the map, the abrupt shift very strikingly; and it is seen also in the limestone limit *west* of the village.

Such apparent shifts may correspond to actual westward or eastward displacements produced since the time when the deposits were formed; or they may indicate the course of the shore-lines of the ancient sea in which the deposits accumulated. Which is the right explanation is an important question.

c. In central Berkshire, within the limestone limits, south of the line of Lee and Stockbridge, a region of high hills and ridges comprising Bear Mountain, covers the northern part of the town of Monterey and small parts of adjoining towns. It has an east-and-west course, cuts short the limestone area, gives an east-and-west course to the Housatonic River (and to roads and railways), and to the limestone area of southern Monterey, (see map), and thus disturbs or goes athwart the feature-lines and Taconic trends of the valley. But the eastern limit of the limestone has no abrupt shift in its course. The summit of this Bear Mountain region is probably Archæan. The disturbance in the direction of the feature lines, which is apparently due to this area, extends also to ridges west and southwest, as that of Monument Mountain, and those between Monterey and Great Barrington, which have a northwest trend instead of the usual north-by-east.

The question as to the origin of these changes in the courses of the rocks, or those of their outcrops, requires, for a safe reply, a consideration of the facts over a wider range of the formation; and I recall here some of the features in Salisbury, Ct., and farther south.

d. In Canaan and Salisbury the eastern or Stockbridge

* See description of Section I. vol. ii, p. 601, by C. H. Hitchcock. The granite is hornblendic, and I found it to contain zircons.

limestone belt, which has there a width of 3½ miles, comes, on the south, bluntly against the high range of hills of Sharon, Cornwall and Kent, and sends off a southward branch either side; this obstruction is the *occasion* of the subdivision of the limestone into two branches, mentioned on page 271, one in eastern New York to Towner's, the other in Connecticut to New Fairfield. Now, this range of hills has much quartzyte in some parts over the northern end, and also, beyond the quartzyte, gneisses and other rocks, part of which at least (as chondroditic limestones, and other characteristics show) are Archæan. Archæan hills which antedate in uplift and erosion the limestone seem to have determined in this case the shore lines of the early Paleozoic seas, and the area of limestone-making in the waters. At the southern end of this Archæan range (Percival's K1) the two branches of limestone, as Percival first pointed out, make a junction across from Dover to South Kent, which is about half the way to Towner's and New Fairfield; thus binding in one mass the chief range of Canaan-Salisbury limestone that goes to Towner's with the more eastern part that goes to New Fairfield, although the latter has its course among mica schists and gneisses.

e. Another region of abrupt change in the Taconic outlines is that of Pittsfield, at the summit level of the great valley of Berkshire. The height of the wide plain is about 1,000 feet above tide level. It is the place of union of the headwaters of the Housatonic River. The longest of the tributaries, which carries the name of the river, comes in from the eastward along the valley which is made use of by the Boston & Albany railroad. For this and other unexplained reasons, the Pittsfield plain spreads eastward of the usual limestone-limit (as the map shows) by more than a mile; and it is equally remarkable that while, both to the north and south of Pittsfield throughout Berkshire, the limestone area is intersected from north to south by two or more ridges of schists, the Pittsfield region, for a breadth from north to south of four miles, is all limestone, from the Taconic range on the west to the eastern limit in Dalton. Further, this eastward extension of the Pittsfield part of the limestone area is accompanied by a long eastward extension also of the quartzyte formation adjoining it; this formation occurring to the southward of the extension over a large part of northern Washington, to and beyond Ashley Lake, and from there returning westward to Dewey's Station; and less widely to the northeast of the Pittsfield plain. Moreover, within two or three miles east of the quartzyte formation occur zircon-bearing hornblendic rocks, and in one region (in Hinsdale) chondroditic limestone, giving definiteness to the indications of Archæan age.

We thus have evidence of an old Archæan valley opening from a higher region to the eastward into what is now the Pittsfield part of the Housatonic Valley. Besides the chondroditic limestone, in the village of Hinsdale, along a wider part of the valley, southwest of Hinsdale, west of the railroad, I found a large mass of the same limestone, which I think is in place; so that it is probable that limestone of Archæan age first determined the formation of that part of the upper Housatonic valley leading into Pittsfield.

f. The wide Tyringham Valley, which extends southeast from South Lee for five or six miles, and is the course of a broad arm of the Stockbridge limestone, is another case in which the limestone spreads eastward beyond its usual limit, although not by an abrupt shift. The valley is not narrow, like those shaped by modern erosion, although owing much to this cause for its present condition. Moreover, it has the quartzyte formation on much of its eastern side, and, beyond this, Archæan gneisses and hornblende and augitic rocks, with some localities of chondroditic limestone. The South Lee valley, coming down from Becket to the eastward, has similar features for a mile and a half. On the high hill in South Lee between the entrances to the two valleys, the Tyringham and South Lee, there is a large area of hornblendic rocks of Archæan age, where the associated limestone afforded me chondrodite in masses as large as the fist, recalling similar localities in Sussex County, N. J., and Orange County, N. Y.; and the same rocks occur on the opposite side of the South Lee Valley to the northeastward. Archæan limestone occurs also in the bottom of the South Lee valley itself, about a mile from the village.

These facts are here introduced as other illustrations of the influence on the outlines of the Stockbridge limestone areas exerted by preëxisting Archæan channels or bays. They further prove that the great quartzyte formation, which makes the foundation of the Paleozoic of the region, derived its material from Archæan formations of the vicinity not from the fabled Atlantis, which some geologists have looked to for aid in the making of American stratified rocks.

[To be continued.]

ART. XXXI.—*Irish Esker Drift;* by G. H. KINAHAN, M.R.I.A.

UNFORTUNATELY, as I have already pointed out in this Journal, American observers, like the early recorders of the Scotch and the Scandinavian later drifts, have "got mixed;" they confounding together true "Esker drift" and ridges of

"Esker-like drift." This appears to be the case in reference to Prof. Carvill Lewis's statement in the December number of this Journal, where he says that the "Irish Eskers" appear to be adjuncts of the melting of the ice sheets. A protracted and careful examination into the subject seems however to demonstrate that this could not be the case.

On the examination of the adjuncts of the present "live ice" or a snow field, it will be found that the drifts due to the ice or the melting of the snow fields, have more or less an argillaceous character, they rarely except in spots, being clean sands or gravel. Of course rivers, having their origin in glaciers or an ice field, after some time may wash these gravels comparatively clean, but this occurs nearly invariably at some distance from the edge of what may be defined as the margin of the present moraine or glacial drift. Recent washing, that is the washing due to river action since the "great glacial period," cannot be taken into account.

In connection with the marine gravels of the present day, we find that in the open sea-currents, all the detritus is well washed and sifted. Where the sea-currents are strong there is coarse sand or fine gravels; this is generally outside the banks; and in other places there is finer, but still well washed sand; while rarely in eddies or "heads of currents," silt accumulates in small quantities. In bays or estuaries, the sand and gravel accumulations are not as well washed and cleaned; while still higher up in such situations, that is near the head of the bay, the accumulations due to marine action graduate in character into those of this drift from the destruction of which, they have been supplied. The true Irish eskers—that is the eskers of the plain and its associated valleys—have no characters in common with those of the ridges of drift due to the melting of ice or snow fields; and the latter are the ridges now erroneously classed with the Irish eskers. On the other hand, all the characters of the true drift are similar to those of the washed marine drifts; they in some places being well washed fine gravel, in others, sand; in eddies on "heads of current" silt; and in such places as must have been bays and estuaries they graduate into half washed accumulations.

Besides, what seems to have altogether escaped Prof. Lewis's attention is the margin of what I have called the "Esker sea." This everywhere throughout Ireland can be traced, as below it the Esker drift occurs and never above it. This margin varies in altitude, but in general not more so than the present spring tide line round the coasts, as I have already pointed out in papers read before the different Irish and English scientific societies. The tide line at the present time is higher on the east coast of Ireland than on the west; and at the heads of the

different long bays than at their mouths; so with the margin of the Esker sea, it rises as it is followed up the valleys. In some exceptional cases, as in the County Wicklow, the marginal beach of the Esker sea is at an excessive height. But these excessive heights are south of a regular line, they gradually rising from the west, eastward; while south of that line they do not rise. Therefore it seems evident that the line is a fault north of which the land to the eastward rose considerably more than to the westward, subsequent to the accumulating of the Esker drift. The details of this phenomenon are fully given in the Geology of Ireland and need not be here repeated.

The regular relative heights at which the true Esker drift terminates seem to me to be positive proof that it must be an adjunct of a widespread action like that of a sea which had comparative level margins, and not to an erratic water supply like that due to the melting of an ice sheet or snow field, either of which is necessarily "martyr to circumstances," sometimes low, at others high. I would suggest that before positive statements are made in connection with the *true* Irish eskers—that it should first be learned what is a *true esker*.

ART. XXXII.—*Physical Characteristics of the Northern and Northwestern Lakes;* by L. Y. SCHERMERHORN, C.E.

IN the following memoranda an attempt has been made to assemble a part of the latest and most reliable information relating to the Great Lakes. The lately completed lake surveys, made by the United States, have reduced to exactness much that previously was only approximate and the perfection of methods used give a perfection to the results which seldom obtains in surveys covering so great geographical extent and involving so many details.

The water surface of the Great Lakes with the land draining into it presents a total drainage basin of over 270,000 square miles, assembled as follows:

	Area of water surface, square miles.	Area of water shed, square miles.	Aggregate area of basin, square miles.
Lake Superior	31,200	51,600	82,800
St. Mary's River	150	800	950
Lake Michigan	22,450	37,700	60,150
Lake Huron and Georgian Bay	23,800	31,700	55,500
St. Clair River	25	3,800	3,825
Lake St. Clair	410	3,400	3,810
Detroit River	25	1,200	1,225
Lake Erie	9,960	22,700	32,660
Niagara River	15	300	315
Lake Ontario	7,240	21,600	28,840
	95,275	174,800	270,075

The water surface of Lake Superior nearly equals the combined areas of New Hampshire, Vermont, Massachusetts and Connecticut, Lakes Michigan and Huron together nearly equal the area of the State of New York, Lake Erie the combined

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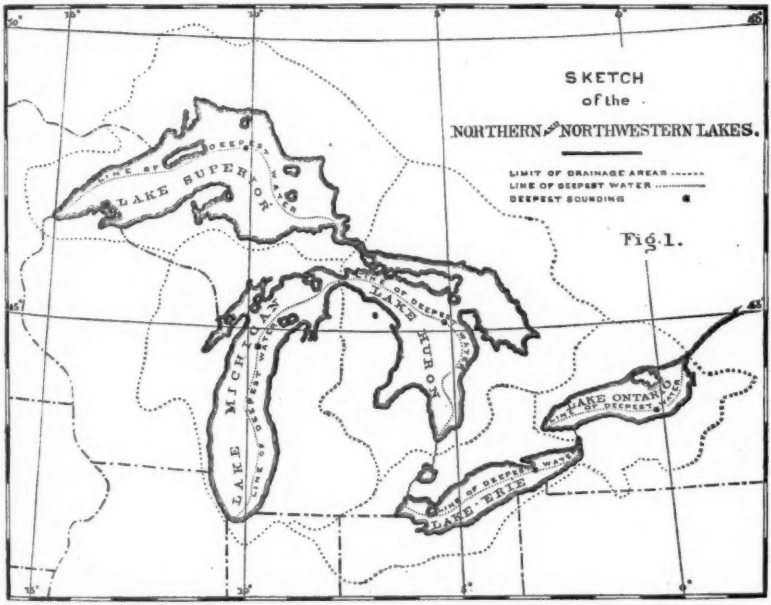
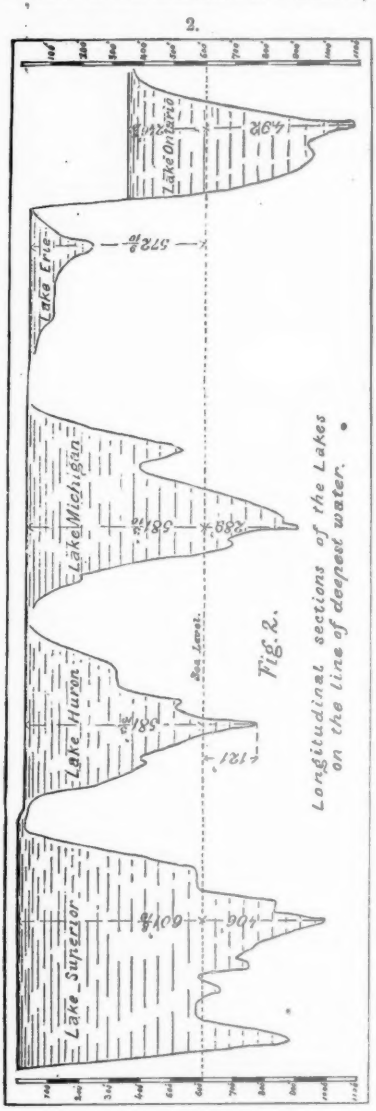


areas of New Jersey and Delaware, and Lake Ontario about three-fourths of the area of Maryland. The combined area of the lakes exceeds the area of England, Wales and Scotland.

The drainage basin of the Great Lakes shown on fig. 1, is a reduction of a very careful compilation of the best authorities and shows at a glance the details stated in the previous table. It shows also that while the line of deepest water does not coincide with the middle line of the lakes, it does approximately coincide with the medial line of lake basin. It will be further observed that, with the exception of Lake Erie, the points of greatest depth quite nearly coincide with the center of figure of each basin. This is believed to be a fact never before noticed, and one that may cast some light upon the geological evolution of the Great Lakes.

The length of shore line of the lakes and their connecting rivers is about 5400 miles, or about equal to the coast line from

Maine to the isthmus of Panama, if the distance be measured along the general contour of the coast, ignoring minor indentations.



The recently perfected levels of the U. S. Lake Surveys, between tide water and the lakes, fixes the elevation of their mean surfaces above mean sea level as follows:

Lake.	Feet.
Ontario	$246\frac{6}{10}$
Erie	$572\frac{8}{10}$
Huron and Michigan	$581\frac{8}{10}$
Superior	$601\frac{8}{10}$

(See fig. 2.)

The difference of $20\frac{1}{2}$ feet between Lakes Superior and Huron occurs in the rapids of St. Mary's River; the $8\frac{4}{10}$ feet between Lakes Huron and Erie mainly in Detroit River.

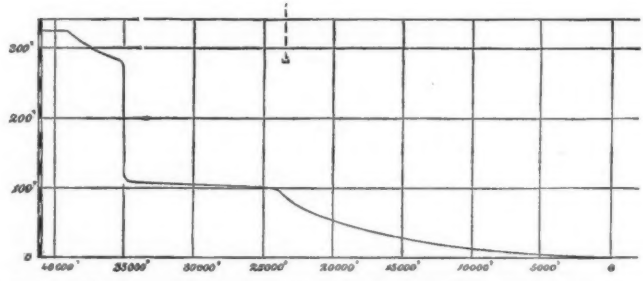
The difference of 326 feet between Lakes Erie and Ontario occurs in the vicinity of Niagara Falls and is principally assembled as follows (see fig. 3): 100 feet in the five miles of rapids between Lewiston and the lower Suspension Bridge, 10 feet in the rapids between the Bridge and the Falls, 160 feet at the Falls,* 50 feet in the rapids immediately above the Falls, and 6 feet in the upper Niagara River.

The mean depth of Lake Superior is about 475 feet; the deepest point (see fig. 2) marks a depth of 1008 feet, or over 406 feet below the level of the sea. Lake

* The height of the Falls is 155 feet on the Canadian side, 161 feet near the site of Terrapin Tower and 169 feet near the east side of the American Falls.

Huron has a mean depth of about 250 and a maximum depth of 702 feet. Lake Michigan has a mean depth of 325 feet and a maximum depth of 870 feet. Lake Erie is comparatively shallow, having an average depth of less than 70 feet and a maximum of 210 feet. Lake Ontario has a mean depth of about 300 feet and a maximum of 738, or nearly 500 feet below the level of the sea. The channels of the rivers connecting the lakes seldom exceed the depth of 50 feet. If the lakes could be drained to the level of the sea, Lake Erie would disappear, Lake Huron reduced to quite insignificant dimensions, Lake Michigan to a length of about 100 miles with a width of 25 or 30 miles, Lake Ontario and Superior, although with diminished areas, would still preserve the dignity of their present titles as *Great Lakes.*

3.



A chemical analysis of water taken from the deepest part of Lake Superior failed under the application of delicate tests to indicate the presence of salt.

The beds of the lakes away from the vicinity of the shore-lines, and at depths exceeding 100 feet, are almost invariably covered with clay. Specimens from the deep soundings of Lake Superior were invariably soft clay varying in color from red, yellow to blue. In the deepest parts the drabs and bluish tints predominate.

The temperature at the deepest points varies little from the mean annual temperature of the surrounding air. The temperature of Lake Superior at depths exceeding 200 feet varies but slightly from 39° F. In Lake Huron, at depths of about 300 feet the temperature in the months of June and August was 52° F., while at a depth of 624 feet the temperature was 42° F., the surface temperature being 52° F. and the air 64° F.

The mean annual rain and melted snow-fall of the several lake basins is as follows: Lake Superior, 29 inches, Lake Huron, 30 inches, Lake Michigan, 32 inches, Lakes Erie and

Ontario, 34 inches. This is about equal to 31 inches on the entire lake basin.

The following represent the average discharges at the outlets of the lakes:

Lake Superior, at St Mary's River	86,000	cu. ft.	per. sec.
Lakes Michigan and Huron, at St. Clair river	225,000	"	"
Lake Erie, at Niagara	265,000	"	"
Lake Ontario, at St. Lawrence river	300,000	"	"

The aggregate discharge of the lakes is double that of the Ohio and nearly equals half the discharge of the Mississippi. The area of the lake basin is a third larger than the basin of the Ohio, or about a fifth the combined areas of the basins of the Mississippi and its affluents. The outflow of the lake basin is slightly less than half the rain fall, while on the Mississippi and Ohio the discharge is about a fourth the rainfall. If the average discharge of the lakes passed through a river one mile wide with a mean velocity of one mile per hour, such a river would have a depth of 40 feet from shore to shore.

The volume of water in the lakes is about 6000 cubic miles, of which Lake Superior contains a little less than one-half. Perhaps a better idea of this volume may be obtained when it is said that it would sustain Niagara Falls in its present condition for about 100 *years*.

In relation to the depth of water on the crest of Niagara Falls it can be easily demonstrated that if the water passed over the Falls in a sheet of uniform thickness for the entire length of the present water way, which is about 3600 linear feet, the depth of the sheet would not exceed 4 feet. It is highly probable that at the apex of the Horseshoe Falls the depth is nearly 20 feet, consequently it may be inferred that the depth of the sheet except in a few places is less than 4 feet.

The principal changes in the elevation of the lake surfaces are those due to the wind and to rainfall. Prof. Whittlesey states that on Aug. 18, 1848, a gale from the N.E. reduced the water level at Buffalo, N. Y., to a point 15½ feet lower than the surface of the lake on Oct. 18, 1849, at which time a terrible gale occurred from the S.W. This was an excessive difference of level and one of rare occurence.

During protracted autumn gales waves have been observed which through reliable means, measured from 15 to 18 feet above the normal surface.

The second class of variations, those due to rainfall, occur with considerable regularity. The lowest water in the year generally occurs in Lakes Ontario, Erie, Michigan and Huron in the months of November and March, and on Superior in March. The highest water occurs on the first named lakes in

June and July, while on Superior it is delayed until September. The average difference, derived from 20 years observation, between the high and low water of the year is as follows:

Lake Superior, 1·2 feet, Michigan and Huron, 1·3, Erie, 1·6, and Ontario, 1·9 feet.

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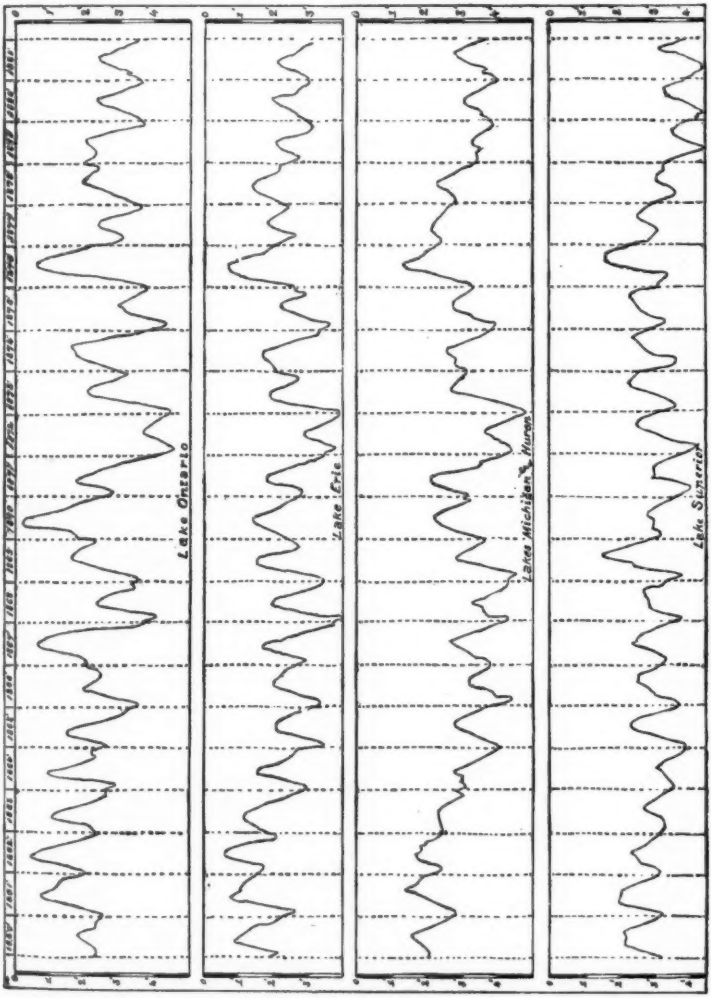


The highest observed stage of the lakes occurred in the summer of 1838, and the lowest in the summer of 1847: the difference between the two stages being about 4½ feet.

The water level of the lakes for the last 20 years is shown in fig. 4 and fails to show, as has been claimed, any recurring cycle of high or low water.

The curves of the last 10 years show a tendency to irregularities which may be due to changes in rainfall and water-shed produced by the rapid destruction of the forests which 10 years ago covered the basin of the upper lakes.

Observations made by the U. S. Survey have established the existence of small tides, which at Chicago had an amplitude of 1½ inches for the neap tide and about 3 inches for the spring tides.

There is still another class of oscillations called *seiches*, which have been already observed in the Swiss Lakes and for which a solution in all respects satisfactory has not been offered. Whenever the lakes are sufficiently free from the disturbing action of wind to permit observations, a quite regular series of small waves, or pulsations can be detected, which have an interval of about 10 minutes from impulse to impulse. These pulsations seem to occur almost without cessation on Lake Superior. Besides having tides in common with the ocean, the lakes have well-defined land and lake breezes; the breeze from the lakes landward commencing in summer at 8 or 10 o'clock A. M., and continuing until sunset and the breeze from the land lakeward from 9 or 10 P. M. until sunrise.

The modifying effect of these large bodies of water upon land areas contiguous to the lakes is noticeable. At Milwaukee, Wis., which is directly upon the shore of Lake Michigan, the mean annual temperature is as follows: winter, 24° F., spring, 41° F., summer, 67° F., autumn, 49° F., annual range, 110° F. At points in the same latitude but from 50 to 100 miles inland, the mean winter and autumn temperatures are about 2° F. lower, and mean spring and summer temperatures nearly 5° F. higher, while the annual range is about 5° F. greater.

ART. XXXIII. — *Mineralogical Notes from the Laboratory of Hamilton College;* by ALBERT H. CHESTER.

1. FUCHSITE.

THIS interesting variety of mica occurs in considerable abundance on Aird Island, a small island in the northern part of Lake Huron near the mouth of the Spanish River and consequently in the district of Algoma, Canada. The matrix is a coarsely crystalline dolomite, and in this the fuchsite occurs in small layers and masses, sometimes associated with white quartz and

generally accompanied by small flakes of silvery mica, from which it is somewhat difficult to separate it for analysis. An analysis* of a pure sample resulted as follows:

	Cairns.	Schafhäutl.
SiO_2	45·49	47·95
Al_2O_3	31·08	34·45
Cr_2O_3	3·09	3·95
Fe_2O_3	trace	1·80
CaO	0·51	0·59
MgO	3·36	0·71
K_2O	9·76	10·75
Na_2O	0·90	0·37
F		0·35
H_2O	5·85	
Total	100·04	100·92

An analysis of the Tyrol mineral is quoted for comparison. Another determination of the chromium gave 2·88 per cent of Cr_2O_3. The occurrence of chrome mica allied to fuchsite, at various places in Canada, has been mentioned by Dawson,† but I think no analysis has heretofore been published.

The dolomite in which this mineral occurs is interesting, not only on that account, but because of its peculiar appearance, its color, cleavage and crystalline characteristics, causing it to be readily mistaken for calcite.

The analysis‡ is as follows:

$CaCO_3$	52·83	per cent.
$MgCO_3$	40·39	"
$FeCO_3$	5·77	"
SiO_2	0·20	"
Al_2O_3	0·60	"
$CaSO_4$	0·34	"
H_2O	0·14	"
Total	100·27	

This shows it to be a true dolomite in which part of the carbonate of magnesium is replaced by carbonate of iron. It is the common rock of the vicinity, but the fuchsite is found in it only at one place, on the eastern end of the island, the area containing the mineral measuring not more than thirty by fifty feet.

* By Mr. F. I. Cairns.
† Geology of Canada for 1863, p. 494.
‡ By Mr. William N. DeRegt.

2. Pink Celestite.

The occurrence of celestite, in connection with strontianite, in the rocks of the Clinton group, has received casual notice by Professor O. Root,* and it has also been noticed since in various lists of mineral localities. It occurs in nodules and geodes, not only in the limestone and sandstone beds, but also in the oölitic iron ore beds of this vicinity. The best examples are to be found at the stone quarries near Lairdsville, about two miles west of Hamilton College, where it occurs abundantly in masses made up of prismatic crystals, sometimes so slender as to give a fibrous appearance to the specimens. In rare instances the crystals are bladed, and radiate from a center in fan-like shapes. These specimens are often coated with strontianite, which is generally of a mealy character, though sometimes in small crystals. The peculiarity of this celestite which makes it most interesting is its color, which is usually a delicate pink or flesh color, though sometimes it has the ordinary dull bluish tint. Occasionally both colors are seen on the same specimen, but more often it is distinctly one or the other.

An analysis† of this celestite gave the following results:

SrO	46·71 per cent.
BaO	7·28 "
CaO	2·01 "
SO_3	43·20 "
SiO_2	0·28 "
Total	100·38

This corresponds to the following proportions of the three sulphates:

$SrSO_4$	84·09
$BaSO_4$	11·05
$CaSO_4$	4·86

The mineral has frequently been called baryto-celestite, though as far as I can find there is no published analysis of it. From the above calculation the ratio of $S_2SO_4 : BaSO_4 : CaSO_4$ is about 10 : 1 : 1, but the mineral is undoubtedly a mere mixture of the three nearly isomorphous sulphates. A similar mixture, but without the $CaSO_4$ is described by Collie,‡ from Clifton, near Bristol, England, who gives a number of analyses of celestite containing barium sulphate in varying proportions and

* This Journal, II, vol. xiii, p. 264.
† By Mr. F. I. Cairns.
‡ Min. Mag., ii, p. 220.

arrives at the same conclusion. The crystals I have been able to find on these specimens are few, small and imperfect, but the faces *O*, 1-$\bar{\imath}$ and $\frac{1}{2}$-$\bar{\imath}$ have been recognized showing angles approximately near the correct ones.

3. Zinkenite.

A sample of bindheimite from the Stewart Mine, Sevier County, Ark., has at its center a compact massive mineral of dark gray color, consisting of lead, antimony and sulphur only. A partial analysis of the pure homogeneous mineral shows 34·77 per cent of lead, and indicates that it is zinkenite. The occurrence of this rare mineral among the Arkansas antimony ores is suggested by Professor Charles E. Wait;* and Mr. W. F. Hildebrand† describes zinkenite from Colorado very similar to that noticed above.

4. Brochantite.

A specimen of brochantite from Chili gave the following analysis, after deducting 4·45 per cent of insoluble matter, and calculating to one hundred per cent.

CuO	71·73
SO_3	18·21
H_2O	10·06

This corresponds well with the formula $Cu_4SO_7+2\frac{1}{2}H_2O$, which requires CuO 71·84, SO_3 18·16 and H_2O 10·00. The mineral occurs in small tufts of delicate fibrous crystals, verdigris to emerald-green in color, associated with linarite, in a quartz matrix.

5. Pectolite.

A specimen of okenite, so-called, from Disco Island, Greenland, afforded the following analysis:

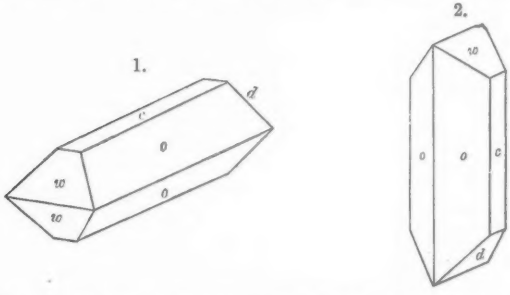
SiO_2	52·86
CaO	34·33
Al_2O_3	0·71
Na_2O	7·50
K_2O	0·47
H_2O	4·70
Total	100·57

* Trans. Am. Inst. Min. Eng., vol. viii, p. 51.
† U. S. Geol. Surv. Bull. 20, p. 93.

This is evidently pectolite, as is probably much that is now called okenite from the same locality. The specimen examined is made up of a mass of fine interlaced fibers, pure white in color, with a sub-pearly luster, and forming a layer about an inch in thickness.

6. Hemimorphic crystals of Barite.

The crystals of barite from DeKalb, St. Lawrence Co., N. Y., described by G. H. Williams,* exhibit the following macrodomes besides the one he mentions: $1\text{-}\bar{1}$ (d), $\frac{1}{4}\text{-}\bar{1}$ and the rare one $\frac{2}{5}\text{-}\bar{1}$ (w). The crystals are generally so grouped together that one doubly terminated cannot often be obtained, but a study of the few that have been observed shows them to be hemimorphic and quite different from any heretofore described. The crystals are all alike and have the form given below; fig. 1 shows one in the usual position, while in fig. 2 the brachy-



diagonal is made vertical. Measured with a hand goniometer $O \wedge \frac{2}{5}\text{-}\bar{1}$ ($c \wedge w$) is found to be 133°, corresponding closely with the angle given by von Kokscharow,† 132° 58′ 25″. As mentioned before, all the doubly terminated crystals found show this dome on one end, and it is also quite often seen on the broken and grouped crystals which show but one termination, though the face $\frac{1}{2}\text{-}\bar{1}$ (d) is rather more common. A few singly terminated crystals were found with both domes. In these cases the curious alteration noticed by Williams is well shown, the faces $\frac{2}{5}\text{-}\bar{1}$ being changed to the chalk-like material which he describes, while the next face, $\frac{1}{2}\text{-}\bar{1}$, is colorless and transparent, or sometimes altered on the edges, leaving a triangular spot of unaltered material in the center of the face. It is worthy of notice that this form, so rarely seen heretofore, should be so common in this one locality.

* Johns Hopkins Univ. Circ., No. 29, p. 61, 1884.
† Min. Russl., vii, p. 54, 1875.

Other hemimorphic crystals of barite have been described by Reuss,* by Zepharovich,† and by Schrauf.‡ These forms are all given in Schrauf's Atlas, figs. 4, 12 and 15, under Baryt. The first two are hemimorphic in the direction of the same axis as the crystals from DeKalb, and the other in the line of the vertical axis. While all three are much more complicated than the simple one described here, none of them shows the face $\frac{2}{3}\text{-}\bar{1}$.

The symbols used here correspond to the more common position of barite, where the plane of the principal cleavage is made the basal pinacoid. The hemimorphism is better shown, as in fig. 2 above, by returning to the old system, still used by some authorities, where this plane is made the brachypinacoid, requiring of course a change of the symbols.

7. Pseudomorphs of Cerargyrite after Pyrargyrite.

These interesting pseudomorphs were found among some ores and minerals from the Horn Silver Mine at Frisco, Utah, and are apparently not uncommon there. The matrix is sometimes a white amorphous silica, easily crumbled and containing much water. It is evidently a variety of opal and closely related to the geyserite of our Western hot springs. In other cases the matrix is nearly pure barite, always distinctly crystalline and occasionally seen in minute crystals. In color it is generally white or grayish, but occasionally it takes delicate lilac tints. Scattered somewhat sparsely through these two we find crystals of a dark color which grade all the way from pure pyrargyrite to pure cerargyrite. They are from 2 mm. to 4 mm. in diameter and up to 10 mm. in length. Though rough externally they are easily seen to be in hexagonal prisms and occasionally show rhombohedral terminations.

Some of these crystals are found on examination to be pure unaltered pyrargyrite, consisting of sulphantimonide of silver with a little arsenic. Many of them are partially altered to cerargyrite, usually in an irregular manner, but occasionally are only altered on the outside leaving a core of pyrargyrite. Quite a number of them are completely changed and are chloride of silver throughout. This is then a case of pseudomorphism by alteration and not a simple filling with chloride of silver of cavities left after the removal of pyrargyrite crystals.

* Ber. Ak. Wien, lix, p. 623, 1869.
† "Lotos," p. 8, 1870.
‡ Ber. Ak. Wien, lxiv, p. 199, 1871.

8. Scorodite.

This mineral is also found among the specimens from the Horn Silver Mine, and particularly in connection with the amorphous sulphate of lead so common there. It does not occur abundantly, but in very thin crystalline crusts of the characteristic pale green color. and also in amorphous layers which shade from yellow to dull brown. The mineral occurs in such thin layers, and so mixed with foreign matters, that a pure sample for analysis can hardly be obtained, but before the blowpipe it reacts for arsenic acid, iron and water, and behaves in all respects like scorodite. So few localities of this mineral have been found that this occurrence is thought worth a notice here.

9. Bismutite.

Some samples of a mineral from near Casher's Valley, Jackson Co., N. C., sent here for identification, prove to be bismutite. It occurs in a narrow vein affording only small masses, the largest being about the size of a pigeon's egg, associated with dark red or black garnet, white mica and quartz, and rarely black tourmaline, the bismutite forming the matrix of the other minerals. As usual it has various colors, the purest and most unaltered being light apple green, while some parts are dark gray. It shades from these colors through yellow and light gray to chalky white in the amorphous parts. It has a laminated structure, in some instances appearing almost columnar. The specific gravity of the purest is 7·4 to 7·5.

Analysis of the mineral* gave results as follws:

Bi_2O_3	86·36	per cent.
CO_2	7·79	"
H_2O	2·02	"
Insoluble	3·63	"
Total	99·80	

It was not easy to select material entirely free from gangue but this was not necessary, as the solution of the mineral in dilute nitric acid is complete, leaving a residue of mica and quartz only. Deducting this residue and calculating to one hundred per cent gives:

Bi_2O_3	89·80	per cent.
CO_2	8·10	"
H_2O	2·10	"

The formula suggested is $Bi_2C_2O_6+2Bi_2H_2O_4$, requiring Bi_2O_3 89·31, CO_2 8·40 and H_2O 2·29, which agrees very

* By Mr. F. I. Cairns.

well with the figures given above. The mineral is therefore a combination of bismuth carbonate and hydrate. Comparing this formula with BiC_5 which is given by Weisbach* for his bismutosphærite, or rather with its equivalent $Bi_2C_2O_9+2Bi_2O_3$, we see that they differ only in the hydration of the bismuth oxide. If we regard the loss in Winkler's analysis as water, and after deducting the silica found, calculate to one hundred per cent, it becomes Bi_2O_3 88·83, CO_2 8·90 and H_2O 2·18, also quite near the figures required by the formula.

It is to be hoped that there will be a new examination of bismutosphærite, for it certainly is a suspicious circumstance that the loss in the analysis given, an analysis on which a new name is based, should be exactly the amount of water required to make it the well-known mineral bismutite.

Clinton, N. Y., February 16, 1887.

ART. XXXIV.—*The Topography and Geology of the Cross Timbers and surrounding regions in Northern Texas;* by ROBERT T. HILL.† With a Map, Plate VI.

THE Cross Timbers of Texas are two long and narrow strips of forest region between the 96th and 99th meridians, extending parallel to each other from the Indian Territory southward to the central portion of the State, forming a marked exception to the usual prairie features of that country. They have been delineated upon several maps, but most accurately upon the one accompanying the "Report on the Cotton Production of the State of Texas, with a Discussion of the Agricultural Features of the State," by R. H. Loughridge, Ph.D., Special Agent of the Tenth Census,‡ which has been adopted in the map illustrating the areal distribution of the geologic formations of the United States, published in vol. v, of the Annual Reports of the Director of the U. S. Geological Survey.

The traveler, in crossing this region of Texas from east to west, along the line of the Texas and Pacific railroad, views the Cross Timbers merely as a grateful relief to the monotony of the prairies, and sees little in them worth remembering. To the more careful observer, however, there are numerous points of interest bearing on their topographic and geologic relations, some of which are worthy of presentation.

* Jahrb. Berg-Hütt., 1877.

† Read before the Philosophical Society of Washington, Jan. 29, 1877.

‡ Rep. Tenth Census, vol. v, pt. I, 1884, pp. 653–831.

The literature hitherto published on the subject conveys but vague ideas of the real nature of the Cross Timbers, and usually ignores the discussion of their physical features. In fact they have always been treated together as one phenomenon, and but little intimation has been made of the differences existing between them. Neither has much of definite value been published on the surrounding region, for which reason it will be necessary to include it in this discussion.

The Upper Cross Timbers.

From their greater altitude and their position relative to the flow of the rivers, the more western of the Cross Timbers, although geologically lower in the series, is known as the Upper, in distinction from the eastern, or Lower. It extends southward from the Indian Territory, through the counties of Montague, Wise, Jack, Parker, Hood, Erath and Comanche, to near the Colorado River. Its eastern border at every point is clearly defined, the adjoining prairie region being invariably much higher in altitude. The western border is not so sharply marked, but it approximately coincides with the 98th meridian until near the 32d degree of latitude, when it bends to the westward, losing its identity by "thinning out," so that the boundary between the wooded and prairie region is not always apparent. The surface soil usually consists of an exceedingly fine-grained siliceous sand, which is the detritus of the underlying strata. This sand is utterly untenacious, except when wet, and is readily distributed by the high winds over the surface so as to effectually conceal the underlying strata. A small amount of red clay from a neighboring stratum gives to the sand, when mixed with it, a dirt-yellow color. Although destitute of turf, the surface is covered with a thick growth of stunted trees and bushes, consisting mainly of the post oak (*Quercus obtusiloba*) and the black jack (*Q. nigra*), accompanied by elms and hackberries, and many annuals and perennials that accommodate their appearance to the time of rainfall. This flora is nearly constant throughout the entire extent of the Upper Cross Timbers, and most of its species also occur in the lower member. The character of the soil, as above described, is also constant along the eastern edge, but is varied along the western half of the timbers by the presence of a crumbling, fine-pebble conglomerate.

The Lower Cross Timbers.

The lower Cross Timbers are located about fifty miles east of the upper belt, and extend in a direction approximately parallel to it. They are separated their entire length by a prairie region, utterly destitute of timber. The western mar-

gin of the Lower Cross Timbers is clearly defined, as is the case with the eastern edge of the Upper member; but, instead of being below the level of the prairie it is always at a higher altitude. The soil of the Lower Cross Timbers, although also arenaceous, differs from that of the Upper in many respects. It is ferruginous and more fertile, averaging less than ninety per cent of insoluble silica, while that of the Upper usually exceeds ninety-seven. The difference in fertility of the soils produces a varietal difference in the flora, the trees attaining much larger proportions and the number of species being slightly greater. The average width of the Lower Cross Timbers does not exceed fifteen miles, and they lose their identity near the Brazos River, at Waco.

It is now evident that the resemblances of the two belts of timber are only of a general character, and an examination into their geologic relations will show many more important differences than those already pointed out.

Prevalent Theories as to the Cross Timbers.

The occurrence of these anomalous belts of timbered region, extending in a direction at right angles to the streams, has been productive of many hypotheses concerning their origin. Unfortunately, very few geologists have heretofore visited the country, and hence most of these hypotheses have been based upon compilation or tradition. Most of them imply that the arenaceous soils of the Cross Timbers have resulted from the sediments of post-Cretaceous aqueous channels or basins, which have been preserved intact from destructive denudation. These theories are partially derived from the relative position of the timbers to the adjacent prairies. One of them is that they represent arms, or inlets, of the Tertiary sea*—a theory made plausible by the proximity of their southern termini to the western borders of the Tertiary area, and the occurrence in one of the Timbers of a molluscan fauna, presenting at the first glance a Tertiary facies. A second theory is that they are the beds of extinct lakes, and a third, that they represent the channels of Quaternary rivers,† the directions of which indicate the former general slope of the surface of the country. The current opinions concerning their geologic age have been as

* "First Annual Report of the Geological and Agricultural Survey of the State of Texas, by S. B. Buckley, State Geologist," pp. 61, 62. Houston, 1874.

† Dr. Loughridge speaks thus of the river channel theory: "In many points along its course the general surface of the belt is lower than the adjoining prairies, and the general features of the lower Cross Timbers almost lead to the conclusion that at some time a deep trough-like valley connected Red (perhaps the Canadian) and Brazos rivers, probably forming the bed of the former river and conveying its waters to the Gulf through the present channel of the Brazos, and that by some agency this valley was filled with clays and sands and the present channel of the river formed."—Rep. on Cotton Production, p. 29.

diverse as those concerning their origin. Dr. S. B. Buckley, in his "First Annual Report of the Agricultural and Geological Survey of the State of Texas," erroneously calls the lower member the "upper" (p. 61) in one place, and refers them to the "Miocene," and on the next page he speaks of them both as probably "Tertiary." Messrs. Blake and Hitchcock, on their geological map of the United States (1876), delineate only the lower member of the Cross Timbers, and color it Eocene. Mr. A. R. Roessler's series of county maps of Texas represent the upper timbers as Tertiary. A prominent authority on the Southern States Tertiaries, in a private letter, maintains that the upper member is Carboniferous, and the lower one of the Cretaceous period (Ripley). Dr. R. H. Loughridge, in the valuable treatise so often mentioned in this paper, gives the best account of them that I have seen in print, and calls them "stratified Quaternary drift." Mr. W. J. McGee, naturally accepting Dr. Loughridge's theory as the most plausible, incorporated it in his Map of the United States, accompanying the Fifth Annual Report of the Director of the U. S. Geological Survey, Washington, D. C., 1886.*

With all of these theories in mind, I must confess that I visited the region this summer with a preconceived idea that I should find some one of them approximately true, and I was greatly surprised to find them all equally erroneous.

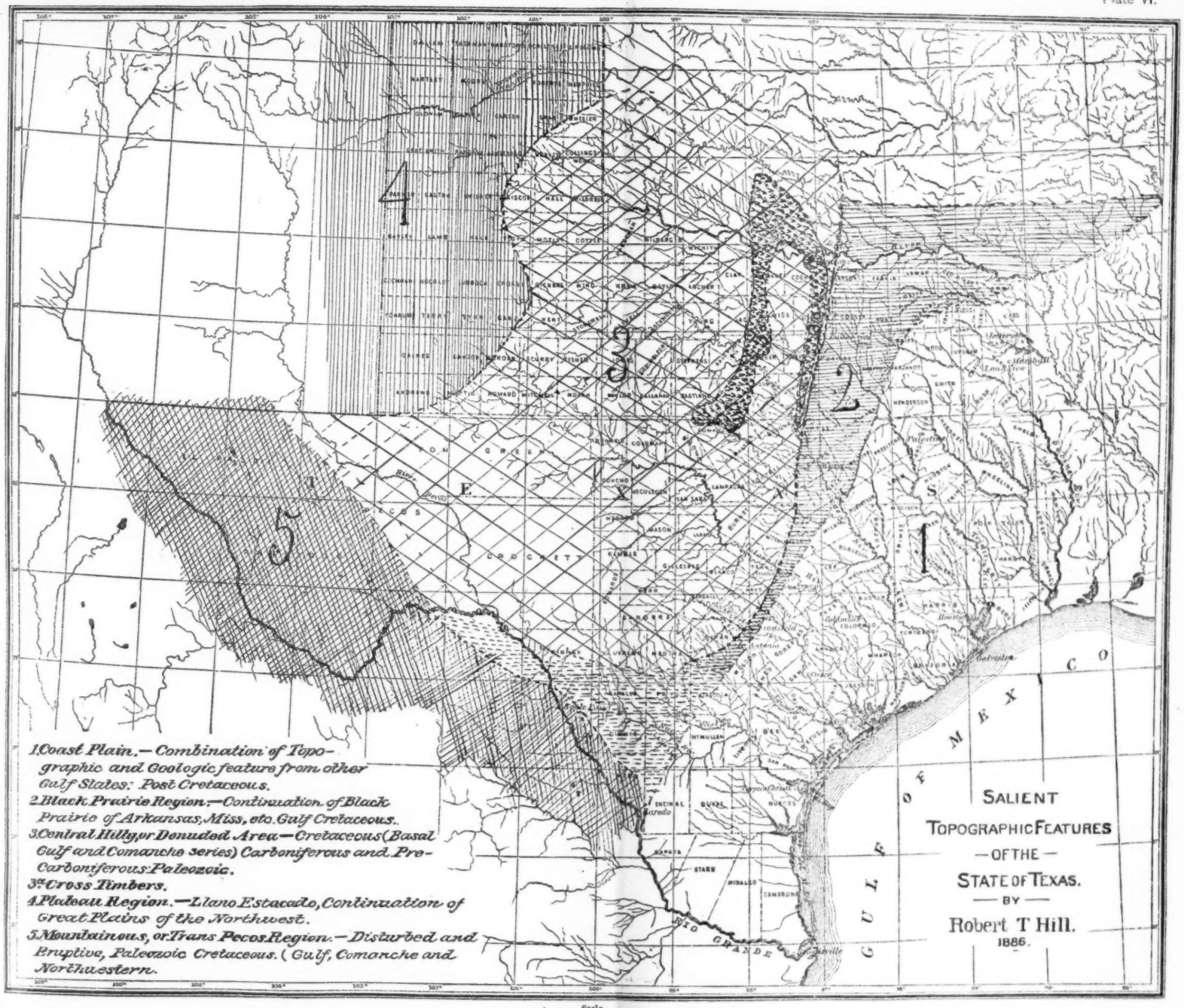
Topographic and geologic characteristics.

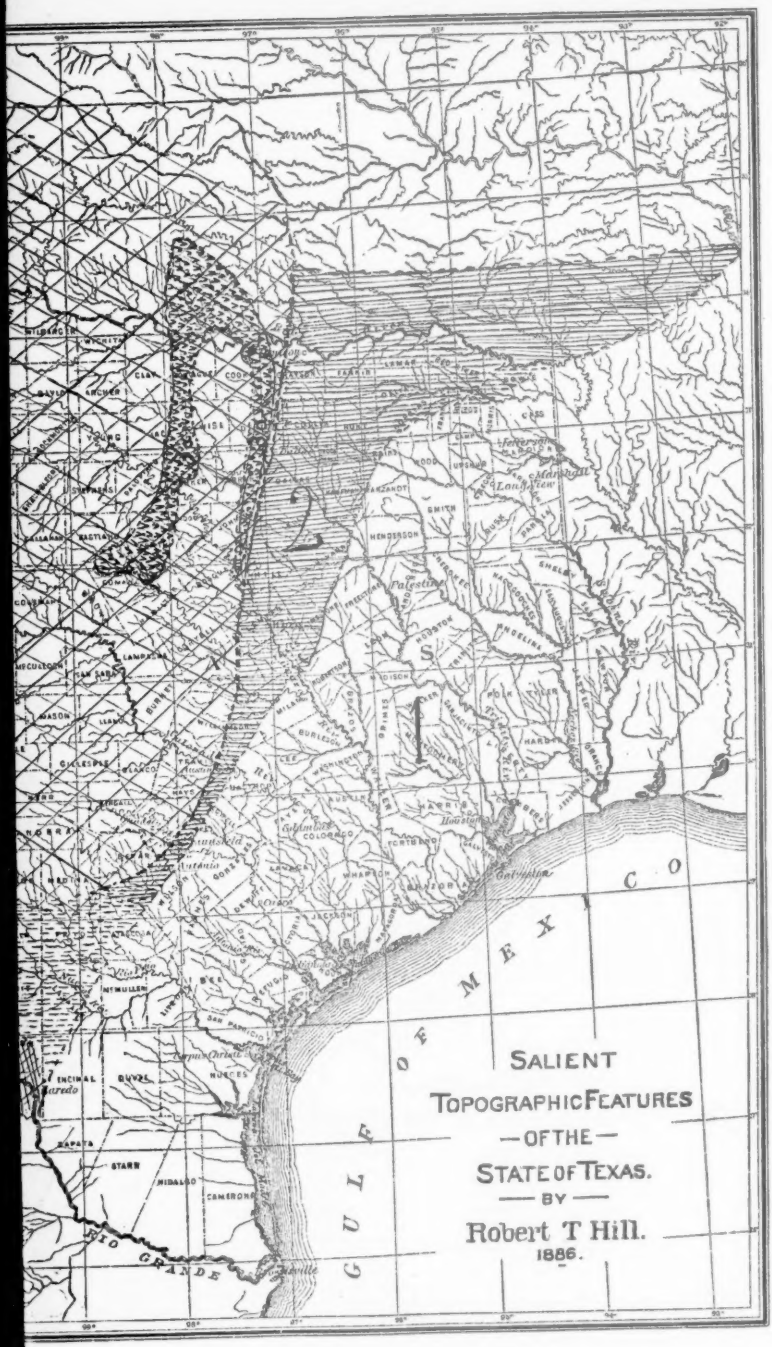
Before a proper appreciation of the relations of the two members of the Cross Timbers to each other can be arrived at, it is necessary to briefly review the salient topographical features of this portion of the State of Texas.† The river drainage of the State indicates the only general feature in its topography—a slope of the surface from northwest to southeast; but even to this feature there are several important exceptions. For my own convenience I have divided the topographic features of the State into the following broad areas:

First.—The Coast Plain, a continuation of the topographic features of the Gulf States so far as they represent old outlines of Post-Cretaceous sedimentation of the Gulf of Mexico. Although a portion of the Cretaceous strata for a short distance west of it could be classified geologically with this Coast plain, its topographic border is made to coincide with the interior border of the marine Tertiary, the plain being mostly a forest-covered section of country, and at a much lower altitude than the prairie region.

Second.—The "Black Prairie Region." This constitutes an elongated, triangular region continuing from Arkansas and

* Mr. C. H. Hitchcock also accepts this in his late map, 1886. † See map.


1. Coast Plain.—Combination of Topographic and Geologic feature from other Gulf States: Post Cretaceous.
2. Black Prairie Region:—Continuation of Black Prairie of Arkansas, Miss, etc. Gulf Cretaceous.
3. Central Hilly, or Denuded Area—Cretaceous (Basal Gulf and Comanche series) Carboniferous and Pre-Carboniferous: Paleozoic.
3a. Cross Timbers.
4. Plateau Region.—Llano Estacado, Continuation of Great Plains of the Northwest.
5. Mountainous, or Trans Pecos Region.—Disturbed and Eruptive, Paleozoic Cretaceous. (Gulf, Comanche and Northwestern.
SALIENT
TOPOGRAPHIC FEATURES
—OF THE—
STATE OF TEXAS.
—BY—
Robert T Hill.
1886.
GULF OF MEXICO
RIO GRANDE
Scale.


SALIENT
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GULF OF MEXICO
RIO GRANDE
EL PASO
PANHANDLE
STAKED PLAIN
EDWARDS PLATEAU
COLORADO
BRAZOS
TRINITY
NECHES
SABINE
RED
CANADIAN
WICHITA
BRAZOS
PECOS
NUECES
GUADALUPE
SAN ANTONIO
LAREDO
GALVESTON
HOUSTON
AUSTIN
DALLAS
FORT WORTH
WACO
ABILENE
SAN ANGELO
MIDLAND
ODESSA
BIG SPRING
LUBBOCK
AMARILLO
CANYON
CLARENDON
MEMPHIS
PARIS
TEXARKANA
JEFFERSON
MARSHALL
LONGVIEW
TYLER
PALESTINE
NACOGDOCHES
LUFKIN
BEAUMONT
PORT ARTHUR
ORANGE
CORPUS CHRISTI
BROWNSVILLE
HARLINGEN
MCALLEN
EAGLE PASS
DEL RIO
SONORA
ABILENE
SWEETWATER
BROWNWOOD
COLEMAN
STEPHENVILLE
GRANBURY
CLEBURNE
DENISON
SHERMAN
GAINESVILLE
WICHITA FALLS
VERNON
CHILLICOTHE
QUANAH
CROSBYTON
PLAINVIEW
HEREFORD
DALHART
PERRYTON
MIAMI
PAMPA
WHEELER
CHILDRESS
ELECTRA
BURKBURNETT
MINERAL WELLS
WEATHERFORD
HAMILTON
GATESVILLE
TEMPLE
BELTON
KILLEEN
GEORGETOWN
ROUND ROCK
AUSTIN
SAN MARCOS
NEW BRAUNFELS
SEGUIN
GONZALES
VICTORIA
CUERO
YOAKUM
HALLETTSVILLE
EDNA
BAY CITY
ANGLETON
LAKE JACKSON
FREEPORT
ALVIN
PEARLAND
LA PORTE
BAYTOWN
CHANNELVIEW
PASADENA
DEER PARK
LA MARQUE
TEXAS CITY
HITCHCOCK
ALVIN
ANGLETON
BRAZORIA
SWEENY
CLUTE
LAKE JACKSON
FREEPORT
SURFSIDE
JONES CREEK
OYSTER CREEK
ANGLETON
BRAZORIA
SWEENY
CLUTE
LAKE JACKSON
FREEPORT
SURFSIDE
JONES CREEK
OYSTER CREEK

Indian Territory into Northern and Central Texas, and immediately adjoining the foregoing topographical division on the west. Its western border follows a line drawn through Dallas and Austin, from Denison to San Antonio, where it makes a western deflection to the Rio Grande. Geologically, this region is also a continuation of the features of the other Gulf States, but beyond its western edge the continuity ceases. It differs from the Coastal Plain in being at a much greater altitude, and consisting almost entirely of a level prairie region. Its altitude is from 450 to 750 feet.

Third.—The Central Denuded or Hilly Region. This area, in itself, embraces a great number of unique and well-marked topographic features, each of which is worthy of a more detailed description than can be here given. It might be called the "butte" region, the "drouth" region, or by any of a dozen local descriptive names equally applicable to it; but its general features are all the result of one great cause, an excessive amount of superficial denudation. It includes all the country west of the Black Prairie Region to the escarpment of the plains, in the northwest, and to the Trans-Pecos mountainous region of the southwest. It embraces a multitude of geologic formations, but there is in it little* or no evidence of local disturbance in the strata. Its altitude is generally between 750 and 2000 feet.

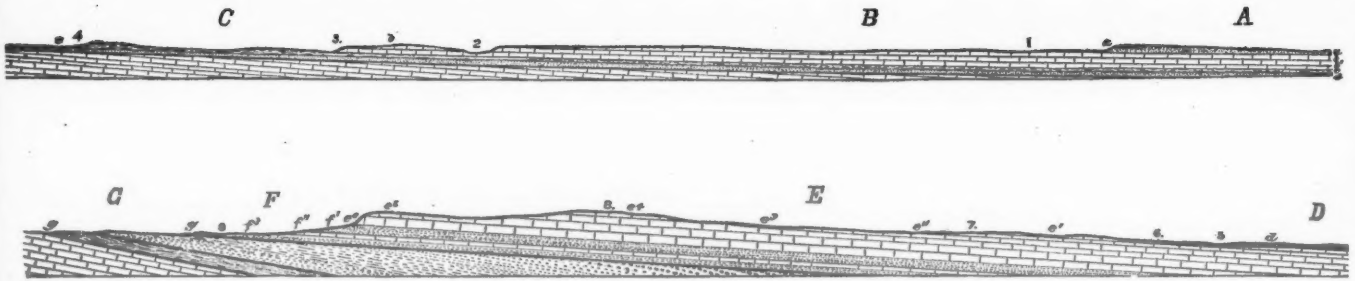
Fourth.—The Plateau, or Pan Handle Region. This comprises the northern and most extensive half of the Llano Estacado, and is a southern continuation of the great plains of Kansas.

Fifth.—The Mountainous or Trans-Pecos Region. Most of the country west of the Pecos consists of highly disturbed, mountainous areas. The general direction of the axes of the disturbances is parallel with the course of the Pecos, the Rio Bravo, and the Sabinas river in Mexico, all which flow nearly due southeast. The eastern border of this area crosses the Rio Grande west of the Pecos, continues in Mexico for a distance, but again crosses the Rio Grande eighteen miles west of Eagle Pass, and for a hundred and fifty miles it extends along the Texas side of that river to below Laredo, where it again crosses it into Mexico.

I have endeavored to delineate this classification of the topographic features upon the accompanying map, plate VI.

The two belts of the Cross Timbers are entirely within the third, or Central Denuded Region, the eastern border of the lower timbers coinciding almost exactly with the western border of the second topographical area. The chief geologic agency in modifying the surface of this region, as before stated, has been subaerial erosion. The only elevation apparent is that which

* No recorded disturbance, I should say. There is an important dislocation of strata in this region to which I shall soon call attention.



GEOLOGIC SECTION ALONG THE LINE OF THE TEXAS AND PACIFIC RAILWAY, FROM ELMO, KAUFMAN COUNTY, TO MILLSAP, PARKER COUNTY.

1. Terrel; 2. Dallas; 3. Eagle Ford; 4. Arlington; 5. Handley; 6. Fort Worth; 7. Ben Brook; 8. Weatherford; 9. Millsap.

A. Coast Plain—Marine Tertiary. B. Black Waxy Prairie—Riply and Rotten Limestone, of Gulf Series. C. Eagle Ford Shales, and accompanying prairies. D. Lower Cross Timbers—Timber Creek Group ("Dakota sandstone?" of Shumard). E. Grand Prairie Region—Comanche (Texas) Division of the Cretaceous. e', e'', e^3, Washita, or upper, division; e^4, e^5, e^6, Lower, or Fredricksburg (Comanche Peak) division. F and G. Upper Cross Timbers—f', f'', f^3, Dinosaur Sands; g, g, Carboniferous Coal-measures. Faunal horizons—e^3, Toxaster elegans Fauna; e'', Horizon of Gryphæa Pitcheri (var. Dilatata) with Ostrea carinata; e^3, Gryphæa Pitcheri, var. Fornicula (Exogyra forniculata; e^4, Ammonites vespertinus; e^5, Hippurites (Caprina) Limestone; e^6, Comanche Peak Fauna, including horizon of Gryphæa Pitcheri with Ostrea Matheroniana.

is common to the other areas, and which was due to the rising of the Rocky Mountain axes. The denudation resulting from the subaerial erosion has been very great, the whole of the geologic series, from the recent to far down into the Carboniferous, having been removed from its center or place of greatest denudation. In traveling in either direction from the center of this region, east or west, and sometimes south, the geologic formations will be passed in ascending series, from the Carboniferous into the Tertiaries. The denudation is progressing now at a rate probably greater than in any time past, and the geologic features are being constantly modified by it. The Tertiary, if it ever existed there,* has already been removed from this vast area, and the Cretaceous is rapidly yielding—in places entirely gone. This fact being true, it is evident that the Cross Timbers cannot represent any post-Cretaceous sediments.

Going from east to west along the line of the Texas Pacific Railway, as I have represented upon the accompanying profile and geologic section—from the area of the least denudation to that of the greatest—let us examine more closely into the relations of the strata, and their connection with the present topographic features. The second topographic area, after passing west of the first, or Coast Plain (with which I shall not deal in this paper), is locally known as the "black waxy," or "white rock" prairie, two names derived respectively from the character of the soil and of the underlying rock. It has such topographic, geologic, and paleontologic resemblance to the "Rotten limestone" of the other Gulf States, as well as direct geographic continuity, that there is no doubt but that it, as well as its immediately adjacent strata, is a continuation of the same formations from those States. The underlying rock (*b*)† is a soft, almost structureless, slightly foraminiferous limestone rich in magnesium, which, on dry exposure, hardens and bleaches to a yellow-white, and on contact with moisture readily decomposes and crumbles. Natural sections, wherever exposed by the creeks or rivers, show that there is a gradual transition from rock to marl and marl to soil. In other words, the top of the rock, when acted upon by infiltrating moisture, is decomposed into the marls and soils. The uniformity of this under-surface decomposition over a large area, together with the tenacity of the soil, results in a level and well-defined prairie region. The eastern edge of this Rotten limestone, where it dips under the higher protecting strata, is much thicker than

* The land divide which probably separated the brackish and fresh-water Tertiaries of the west from the purely marine Tertiaries of the Gulf region may have occupied this region at one time. The marine Tertiaries end in the vicinity of Elmo, Kaufman County (*a'*).

† Letters in parentheses refer to the letters upon the profile and geologic section accompanying.

Geologic Section of the Cretaceous Strata of the State of Texas, as seen along the Line of the Texas thickness, as it occurs throughout the State.

		Position.	History and Synonymy.	Stratigraphy.
Gulf Series.	Upper Cretaceous.	**BASAL TERTIARIES.**		
		NAVARRO BEDS.	Ripley Group of Shumard, 1861. (3) (2) Loughridge, 1884. (4) Included by Rœmer in Kreidebildungen am Fusse des Hochlandes. (5)	Marls, clays, and limestones of varying hardness, and in beds of limited extent. Mostly concealed by the prairie soil.
		Exogyra ponderosa Marl.		
		DALLAS LIMESTONE.	"Austin" Limestone of Shumard, 1860. Wrongly placed by him in series.	Soft magnesian limestone, earthy fracture, fine texture, highly foraminiferous. Blue upon fresh exposure, but decomposing and bleaching shortly after. Agrees, in main, with the same formation as described in other Gulf States.
			Part of Rœmer's Kreide. am Fusse des Hochlandes.	
		Zone of Ostrea bellaplicata.	Part of "Lower Cretaceous" of Shumard, 1860.	Conformable with above by position and faunal continuity. No line of demarkation yet made between the above groups.
	Middle Cretaceous.	**EAGLE FORD SHALES.**	"Arenaceous Group" and "Fish Bed" of Dr. Shumard's "Lower Cretaceous," 1860. Kreide. am Fusse des Hochlandes. Rœmer.	Argillaceous shales, varying from blue at top to yellow in middle, and to blue again at base, but with marked faunal zones.
		TIMBER CREEK GROUP.		Coarse-grained, friable, ferruginous sands, alternating with thin seams of yellow clays. Lignitic.
				Plane of Uncon
Comanche Series.	Lower Cretaceous.	Upper Denison Fauna.	"Lower Cretaceous." (1)	Thin alternations of limestone, sandstones, and shales.
		Cidaris hemigranosus. Toxaster elegans. Exogyra arietina.	"Washita Limestone." (1) " " "Indurated Blue Marl" (1)	Alternating bands of firm yellow limestones and calcareous marls, growing thicker downward. The "blue marl" is the same material.
		Gryphæa Pitcheri (with O. carinata).	"Washita Limestone." (1) Jurassic and Neocomian of Marcou.	Loose bedded or cemented Gryphæas.
		Ammonites vespertinus.		Harder, chalky limestone.
		Exogyra fornicularata.		Ferruginous, calcareous marls, limited.
		Ammonites acutocarinatus.	Upward extension of next two.	Upward continuation of Comanche Peak features from groups below.
		Hippurites Limestone.	"Caprina Limestone." (1)	Hardest limestone of series. Flints. Chalk.
		Comanche Pk. fau. Gryphæa Pitcheri (with O. Math.)	"Fredricksburg" of Rœmer. "Comanche Peak Group."	Crumbling chalky at top; thin hard bands at base, and great bed of Gryphæa Pitcheri.
		Requienia Texana.	"Caprotina Limestone." (1)	Firmer bands of limestone. Fossiliferous.
		DINOSAUR SAND.	Upper Cross Timber. (1)	Pure, uncemented pack sands.
		CARBONIFEROUS.		

This series is one of unbroken sedimentation and faunal continuity from base to top. Subdivisions are temporarily defined by horizons of prominent fossils. Many species continue throughout the entire series.

Upper or Washita Division

Lower or Fredricksburg Div

(1) Trans. St. Louis Acad. of Science, Aug., '60. (2) Trans. St. Louis Acad. of Science, Aug., '61. (5) Kreidebildungen von Texas, '52.

the western, the latter constantly undergoing the process of oblique truncation by erosion. As a result of this action it becomes thinner and thinner toward the west, until it is finally

* For convenient reference and brevity, I have formulated into a section the synonymy, lithology, hitherto published paleontology, and occurrence along the Texas Pacific Railway of these strata. With a variation of thickness according to locality, this section is applicable to the Austin or New Braunfels region.

Pacific Railroad, from Elmo, Kaufman County, to Millsap, Parker County, and, with local Variations of Based upon personal Observation. By Robert T. Hill. *

Paleontology.	Occurrence along Texas Pacific R.R.
	Van Zandt Co. west to Elmo.
"I have been able to recognize the following species common to the Tippah (Miss.) and Navarro (Texas) beds: Nautilus Dekayi, Baculites Tippaensis, B. Spillmani, Purpurea cancellaria, Rapa supraplicata, Strombus densatus, Ficus subdensatus, Pleurotoma Ripleyana, Pholadomya Tippana, P. elegantula, P. chrysardium Spillmani, Legumen elliptica, Silliquaria biplicata, Pecten simplicus, P. Burlingtonensis, and Exogyra costata."—B. F. Shumard, Proc. Bost. Soc. Nat. Hist., 1861.	Elmo and Terrell.
	Terrell to concealed point fifteen miles west of Dallas.
	Narrows southward towards Rio Grande. This and all the succeeding members are exposed along north and south lines from Denison to beyond New Braunpels, and can be transected by going from east to west. They thicken southward.
Inoceramus biformis, Gryphæa vesicularis, Exogyra costata, Ostrea anomiaformis, Arca vulgaris, Radiolites Austinensis, Nautilus Dekayi, Baculites anceps, Helicoceras, Ammonites, Cassidulus æquorus, Hemiaster parasutus.—B. F. Shumard, Aug., 1860. Most of Rœmer's species from the Cretaceous at the foot of the highlands are from the Austin Limestone and the upper (Ripley) beds.	From above point east of Dallas to Eagle Ford, seven miles west of Dallas.
Dr. Shumard's list includes forms of the over and underlying beds.—R. T. H.	
Ostrea bellaplicata Shum.	Escarpment, two miles south of Eagle Ford, and along north and south line to Denison.
Corax, Lamna, Otodus, and other vertebrates in the upper half.	Along face of escarpment and underlying prairie from Eagle Ford to seven miles west. Also at Denison.
Only zone of Inoceramus problematicus, Ostrea congesta, and various undetermined Ammonitidæ. Blue shales at base are barren.	
Ostreidæ, lignites, etc.	Lower Cross Timbers, from point few miles east of Arlington to eight miles west. Thins out to south.
FORMITY BY EROSION.	
Ostrea crenulimargo, Turritella Marnochii, Nucula, Corbula, etc.	Missing at Fort Worth, having been eroded away previous to deposition of above group.
Many species of off-shore fauna, mostly undescribed, in upper bed. Many forms from below. Ananchytes ovatus, Lima Wacoensis, Ammonites Swallovii, Janira occidentalis, J. Texana, Gryphæa sinuata, Marcou; Ostrea Marshii, Marcou; G. Pitcheri bed accompanied by O. carinata.	This upper portion of the Texas Cretaceous occupies a narrow area from Fort Washita to San Antonio; is especially well exposed along Missouri Pacific R.R. Nearly the entire series can be found in a short distance from the city of Fort Worth.
A. vespertinus, formerly A. Texanus. Ancyloceras annulatus, Inoceramus.	Between Fort Worth and Weatherford, forming base of high prairies.
The forniculate and naviate varieties of G. Pitcheri abundant.	Six miles west of Fort Worth, south of Ben Brook, etc.
Ammonites acutocarinatus, Shum., and all of Shumard's typical Comanche Peak fauna in greater abundance.	Top of this group first exposed in bed of Trinity, Fort Worth. Highest summit Ben Brook Station.
"Comanche Peak" fauna, with Hippurites Texanus; Caprina, Requienia, etc.	Traces on buttes S. of Weatherford; typical at Comanche Peak.
Over fifty species have been described which belong here. See Shumard's section. The Gryphæa bed No. 2, with O. Matheroniana, is part.	Well displayed in vicinity of Weatherford, from which point to Millsap, ten miles west, the remainder of this section is regularly exposed in descending series.
Culmination of Requienia Texana; Panopea and many bivalve casts.	
Vertebrate remains only, Dinosauridæ, Chelonidæ, etc.	Upper Cross Timbers, few miles west of Weatherford, to Millsap Station; Sand Hills of Staked Plains.
	Millsap Station.

(3) Proc. Bost. Soc. Nat. Hist., vol. viii, '61. (4) Tenth Census Rep. on Cotton Production, '84, p. 18.

worn away entirely. In the section of the State under consideration this western edge forms an escarpment, as seen along Mountain Creek, in Dallas County (*b*).†

† In the region of the State between San Antonio and Austin the escarpment relation of the two formations is reversed, the Gulf Cretaceous being deposited there at the foot of the disturbed Texas.

Immediately underlying this Rotten limestone, and chiefly exposed beneath its projecting stratum, along the escarpment base, are several hundred feet of barren argillaceous shales (*c*), yellow above, and gradating into blue black at the base, with the huge septaria so familiar to one who has seen the Niobrara shales of the west. Where the protecting limestone has been washed away, the shales weather into a gently undulating prairie, with a predisposition to that character locally known as "hog wallow." This is the second character of prairie, a prairie resulting from weathering of shales; it extends as a narrow strip along the western edge of the Rotten limestone region, but fades out before reaching the center of the State.

Continuing westward the next topographic feature is the belt of forest region known as the "Lower Cross Timbers." Geologically the area occupied by these timbers consists of a series of coarse, friable, arenaceous sandstones, (*d*) alternating with clays, whose position is beneath the shales and limestones; and, like them, its western projecting margin is constantly wearing away. The unique fauna, now being studied by Dr. C. A. White, and the presence of lignites, indicate that the sediments are those of shallow waters; they resemble the basal groups of the cis-Mississippi region,* and, Dr. White believes, the Dakota sandstones of Kansas. Elsewhere than in Texas this group would be considered the base of the Cretaceous; but such is not the case here, for it clearly rests upon four hundred feet of a second, and lower series of limestone strata (*e*) and one that was greatly eroded before these sands were deposited. This is the "Texas" group of the American Cretaceous—the probability of the existence of which I pointed out in a previous paper, and which is now demonstrated to be lower than any of the hitherto described marine Cretaceous of this country.

This limestone formation underlies the third character of prairie, which extends parallel with and between the two Cross Timbers. The strata are bands of varying thickness of yellow-white limestones of a peculiar structure, alternating with calcareous clays and marls of the same color. The prairie extends from four miles east of Fort Worth to seven miles west of Weatherford. In crossing it the strata from top to bottom are successively passed. Its surface is barren and rocky, excepting in rainy seasons, and slopes at a much greater angle to the southeast than the others we have described. This was known to old travelers as the "Grand Prairie," a term which is worthy of preservation. One of the strata of limestone (e^3) presents a

* This and all strata above it in Texas are a continuation of the Alabama, Tennessee, Mississippi and Arkansas Cretaceous and Tertiaries, to which I give the name of Gulf series.

much greater resistance to the constantly attacking forces of erosion than the others. As a result of this fact it forms a table land for many miles, and is the highest portion of the prairie. The huge ammonites* which are characteristic of this horizon, project everywhere through the thin soil. This is the third character of prairie, a prairie resulting from resistance. The western edge of this prairie projects as an escarpment above the next topographic feature that we here describe. The ragged edge is well marked, and from it we look down upon the Upper Cross Timbers to the westward. Sometimes we can see the flat topped buttes,† left by the constantly receding line, as remnants of the formation's former extent. These buttes sometimes appear like islands rising from the depression occupied by the Cross Timbers, but usually they are situated on the edge of the adjacent prairie region. They are generally capped by the same peculiar stratum of limestone,‡ resting upon looser strata that quickly wash away when the cap succumbs. Sometimes they appear as mere hillocks, representing remnants of the buttes from which this protecting stratum has been eroded. These buttes are the most prominent features of this area of greatest denudation, and are distributed over it usually upon and around the edge of the Carboniferous exposures. From the top of these buttes and the edge of Grand Prairie, the Cross Timbers look like the waters of a long and narrow lake viewed from an adjacent highland, and in some cases, the opposite shore, as in Comanche county, may be recognized. But the resemblance to a lake is only superficial. It is a case of pseudomorphism, if I may be allowed to use that expression, wherein the forces of sub-aerial erosion have imitated those of wind and wave. The essential features of shore topography and lacustrine sedimentation are absent. The marks of erosion are plainly evident.

On descending the escarpment at the western edge of the Grand Prairie, we reach the sandy soil of the Upper Cross Timbers. A geologic section will show that the surface soil is detritus of the underlying strata (*f*, *g*), which dip to the east, under the adjacent limestone prairie. This series of sandy strata varies in structure as we descend them. The upper strata abound in Dinosaurian bones and teeth, the lower in Lepidodendrons and Calamites. They mark the contact of the basal Mesozoic and the Carboniferous.

The sands of the eastern half of the Upper Cross Timbers are purely siliceous, fine-grained, and utterly free from any cement-

* *A. vespertinus* Morton, 1834; *A. Texana* Roemer.
† Caprina Limestone of Shumard (e^4).
‡ Comanche Peak Group of Shumard (e^5).

ing matrix. They are so friable that they quickly lose all appearance of original stratification on exposure, and were it not for railroad-cuts and well-borings through the overlying Cretaceous limestone, their true stratigraphic position would still remain obscure. The pure white sands of this series can be traced along the eastern border of the Cross Timbers for over a hundred miles. These sands constitute the receiving reservoir for the artesian wells of Fort Worth and Dallas, their strata dipping at such an angle under the Grand Prairie, that they are reached at a depth of 350 feet beneath the first named place, and about 750 at the latter. The detritus of this stratum has been distributed over most of the Upper Cross Timbers, so as to obscure the exact contact of the Cretaceous—if the Dinosaurian sands be Cretaceous—and the Carboniferous. But close inspection will reveal the underlying Carboniferous sands and conglomerates *in situ*, accompanied by characteristic fossils.

West of the Upper Cross Timbers the Texas Pacific road traverses the Carboniferous for a hundred miles. In places, patches of the Cretaceous are preserved upon it; in others, the Carboniferous itself is greatly eroded. At a point between the 97th and the 99th meridians the greatest denudation has taken place. West of this the succession of the strata is again an ascending one. The red beds of the Jura Trias are intercalated between the Cretaceous and the Carboniferous on the western side of the latter formation. The arenaceous beds are again exposed in places, especially at the white sand hills of the Llano Estacado. Traces of the Laramie and fresh-water Tertiaries may be preserved on the plains, but these are beyond the province of this paper.

With this somewhat lengthy explanation of the relations of the topography and stratigraphy of the region, I think the character of the two Cross Timbers will now be apparent. It is certain that they do not represent lacustrine basins or fluviatile channels, but are simply the detritus of arenaceous strata which occupy well-defined horizons in the geologic series, and which have been exposed by the denudation of the overlying strata. The reason why the timber confines itself to these arenaceous belts is also evident. They afford a suitable matrix for the penetration of the roots of trees, and a constant reservoir for moisture, thus furnishing two of the greatest essentials to forest growth. The absence of fertilizing ingredients in the Upper Timbers also accounts for the exceedingly scrubby growth of the timber, which peculiarity, however, the inhabitants always ascribe to the burning of the adjacent prairies. The barrenness of the prairies, so far as forest growth is concerned, is owing to

the absence of the requisite structural conditions for preservation of moisture, as well as the excess of carbonate of lime in their soils. The difference in fertility between the sandy loams of the Lower Cross Timbers and the dirty sands of the Upper, accounts for the varietal differences of their respective floras. The flora of the Cross Timbers is by no means confined to those two areas, but exist in smaller tracts wherever the soil and structure are favorable. In fact the finest development of the flora has been observed in some of these local patches.

The Cross Timbers end so abruptly upon the maps to the south and north for two reasons. To the south the arenaceous strata are either covered by higher strata, or washed away entirely; the northern termination is usually placed at Red River, because of the absence of correct topographical knowledge concerning its extent in the Indian Territory. It is well known, however, that they extend into that region, and it is probable that the two members there merge into one—the surface becoming more fertile, and the rains more abundant and regular, so that the timber's growth is not necessarily confined to the sandy soils.

It is also now evident that many important differences in the two members of the Cross Timbers are seen in Texas, and that they can no longer be treated alike from an agricultural or geologic standpoint, the lower one being far more fertile and better adapted to human habitation than the upper, which is mostly an arid and sterile region.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Phosphorescence of Alumina.*—E. Becquerel has replied to de Boisbaudran concerning the phosphorescence of alumina. He had examined this earth in 1859 and had found that the phosphorescent light emitted by it was red and that it gave a characteristic spectrum. Precipitated alumina imperfectly calcined emits sometimes a greenish light in the phosphoroscope; but when heated to 1200° or 1400°, the light it gives is always red. Moreover the author had observed the influence of other substances and especially of chromium, upon the intensity of the light, rubies being more luminous than white corundum, though the composition of the light is the same. He has now repeated his experiments, using for the purpose substances furnished by de Boisbaudran himself and therefore identical with those experimented upon by the latter.* Fragments of this alumina, con-

* See the February number of this Journal.

sidered pure, were fixed, by means of gum, upon a piece of mica, placed in the phosphoroscope and excited by the light of the electric arc. They emitted a red light, which, however, was much weaker than that given out by alumina containing chromium under the same circumstances. But after having calcined this pure alumina for fifteen minutes in a porcelain crucible in a blast furnace, it became quite as luminous in the phosphoroscope as the alumina containing chromium and of the same color. Hence he concludes that the alumina upon which de Boisbaudran operated, was not sufficiently calcined. The experiment was then repeated upon pure alumina prepared by himself by calcining pure ammonia alum. The light emitted was the characteristic red light so long ago studied. The addition of chromium then does not change the color of the phosphorescent light, but simply increases its intensity. Becquerel also calls attention to the difference in the luminous phenomena according as they are produced by the electric light in the phosphoroscope or by the electric discharge in vacuo; the former effects being simpler, but not obtainable with all bodies.—*C. R.*, ciii, 1224, Dec., 1886. G. F. B.

2. *On the Crimson Line of Phosphorescent Alumina.*—Crookes has presented to the Royal Society a paper on the color emitted by pure alumina when submitted to the electric discharge in vacuo, in answer to the statements of de Boisbaudran. In 1879 he had stated that "next to the diamond, alumina in the form of ruby is perhaps the most strikingly phosphorescent stone I have examined. It glows with a rich full red; and a remarkable feature is that it is of little consequence what degree of color the earth or stone possesses naturally, the color of the phosphorescence is nearly the same in all cases; chemically precipitated amorphous alumina, rubies of a pale reddish yellow and gems of the prized 'pigeon's blood' color glowing alike in the vacuum." These results, as well as the spectra obtained, he stated further, corroborated Becquerel's observations. In consequence of the opposite results obtained by de Boisbaudran, Crookes has now reëxamined this question with a view to clear up the mystery. On examining a specimen of alumina prepared from tolerably pure aluminum sulphate, shown by the ordinary tests to be free from chromium, the bright crimson line, to which the red phosphorescent light is due, was brightly visible in its spectrum. The aluminum sulphate was then, in separate portions, purified by various processes especially adapted to separate from it any chromium that might be present; the best of these being that given by Wöhler, solution in excess of potassium hydrate and precipitation of the alumina by a current of chlorine. The alumina filtered off, ignited and tested in a radiant matter tube gave as good a crimson line spectrum as did that from the original sulphate. A repetition of this purifying process gave no change in the result. Four possible explanations are offered of the phenomena observed: "(1) the crimson line is due to alumina, but it is capable of being suppressed by an accompanying earth

which concentrates toward one end of the fractionations; (2) the crimson line is not due to alumina, but is due to the presence of an accompanying earth concentrating toward the other end of the fractionations; (3) the crimson line belongs to alumina, but its full development requires certain precautions to be observed in the time and intensity of ignition, degree of exhaustion, or its absolute freedom from alkaline and other bodies carried down by precipitated alumina and difficult to remove by washing; experience not having yet shown which of these precautions are essential to the full development of the crimson line and which are unessential; and (4) the earth alumina is a compound molecule, one of its constituent molecules giving the crimson line. According to this hypothesis alumina would be analogous to yttria."—*Nature*, xxxv, 310, Jan., 1887. G. F. B.

3. *On Phosphorus pentafluoride.*—MOISSAN has continued his researches on phosphorus pentafluoride. He finds that when this gas is submitted to the action of the electric spark, employing Berthelot's arrangement of apparatus, great care being taken to have it absolutely dry, there is no decomposition with sparks which in air do not exceed four centimeters in length; thus confirming the observation of Thorpe. But when sparks were employed which were 15 to 20 centimeters in air, then the walls of the glass vessel were attacked and became dim and the mercury lost its brilliancy. After an hour, the experiment was concluded and the apparatus allowed to cool; the volume had diminished. On adding water, silica was produced, showing the presence of silicium fluoride. The remaining gas, in some cases 15 per cent of the whole, is not absorbed by water and gives the reactions of phosphorus terfluoride. It appears therefore, that under the influence of powerful electric discharges, phosphorus pentafluoride is decomposed into the terfluoride and free fluorine, the latter attacking both the mercury and the glass. Heated in a recurved bell jar to a red heat in presence of an excess of phosphorus vapor, the pentafluoride yields no terfluoride. It is not decomposed by sulphur at 440° nor by iodine at 500°; but preserved in glass vessels, it attacks the glass if a trace of moisture be present, forming silicium fluoride and phosphoryl fluoride. The analysis of the pentafluoride was effected by the author in two ways: (1) a measured volume of the gas was absorbed by an alkaline solution, the filtered solution precipitated by molybdic acid, the precipitate filtered off, washed, dissolved, and the phosphoric acid precipitated as ammonium-magnesium phosphate. (2) the alkaline solution, after absorbing the gas, is decanted into a capsule, and, with the wash waters, is evaporated to dryness on the water bath with the addition of a little pure silica. The saline residue is treated with sulphuric acid and evaporated till white fumes of the acid appear. After cooling, the whole is diluted, neutralized with ammonia and in the filtrate, the phosphoric acid is determined as ammonium-magnesium phosphate.—*C. R.*, ciii, 1257, Dec., 1886. G. F. B.

4. *On Phosphorus Tetroxide.*—THORPE and TUTTON have studied the products obtained by the slow combustion of phosphorus in dry air. If these products are aspirated through glass tubes heated by steam, they are free from admixed phosphorus. A quantity of these mixed oxides was transferred to a tube previously filled with dry carbon dioxide, the end of the tube was drawn out, attached to a Sprengel pump, carefully exhausted and sealed. On heating it to about 290°, the white mass appeared to change; a considerable amount of the orange-red suboxide was seen to form, and at some distance beyond was a sublimate of clear, transparent and highly lustrous crystals, which could be heated to 100° without change, their edges remaining perfectly sharp. On heating to 180° in a sulphuric acid bath, they volatilized and re-condensed just above the level of the acid. They polarized light powerfully and are probably orthorhombic in form. The crystals are extremely deliquescent and are dissolved instantly by water with considerable evolution of heat, forming an acid solution. This solution precipitates silver nitrate solution, the white precipitate blackening rapidly. It also reduces mercuric to mercurous chloride, but decolorizes permanganate only very slowly. With magnesia mixture, it gives at once a precipitate of ammonium-magnesium phosphate; and the filtrate which contains magnesium chloride in excess, gives, after standing for some time, an abundant precipitate of phospho-molybdic acid. Hence this solution contains both phosphoric and phosphorous acids. To fix the composition of the crystals, weighed quantities were allowed to deliquesce in the air, and the diluted solution was evaporated with nitric acid, the phosphoric acid in it being determined as usual. In two determinations the percentage of phosphorus present, was 49·09 and 49·46; the calculated value for P_2O_4 being 49·20. Hence the authors think the new oxide is the tetroxide corresponding to the analogous oxides of nitrogen and antimony. The molecular weight however is yet to be obtained by means of a vapor density determination.—*J. Chem. Soc.*, xlix, 833–839, Dec., 1886. G. F. B.

5. *On a hydrated Silicium phosphate.*—HAUTEFEUILLE and MARGOTTET have obtained a compound, having the formula $SiO_2 . (P_2O_5)_2 . (H_2O)_2$ by evaporating a solution of silica in phosphoric acid at 125°. Globular spherical concretions are formed consisting of concentric zones of prismatic crystals, which polarize light strongly. Water at the ordinary temperature decomposes the new body into phosphoric acid and gelatinous silica.—*C. R.*, civ, 56–57, Jan., 1887. G. F. B.

6. *The Freezing of Aerated Water.*—Mr. GEORGE MAN has made a number of experiments upon this subject and thus sums up the experimental results: (1) In a thin ice coating, the upper or surface half contains barely a trace of eliminated air, while its under or bottom half contained 0·08 cubic inch of air in each pound of ice. (2) A surface coating of ice 1½ inch thick contained 0·15 cubic inch of air in each pound weight, while an

entirely frozen mass contained 0·59 cubic inch of air in each pound weight. (3) The freezing of a limited body of water which had first been frozen over and the surface ice removed, points still more strikingly to the concentration of air in solution; for this contained 0·89 cubic inch of air in each pound weight, compared with 0·15 cubic inch in surface ice, and 0·59 cubic inch in an entirely frozen mass.—*Nature*, Feb. 3, 1887, p. 325.

J. T.

7. *Transmission of Electricity of feeble tension by hot air.*—In 1853, M. Ed. Becquerel discovered that gases of a high temperature became conductors of electricity even of feeble electromotive force. M. Blondlot has confirmed the results of Becquerel. With an electromotive force of $\frac{1}{1000}$ of a Volt, the transfer of electricity took place when the gas or air attained the temperature of red heat. Ohm's law does not seem to be fulfilled by this phenomenon. Hot air has not electrical resistance properly so-called. The author believes that the mechanism of the transmission of electricity in this case is due to what Faraday termed convection of electricity.—*Comptes Rendus*, No. 5, Jan. 31, 1887, p. 283.

J. T.

8. *Aperiodic Electrometers.*—M. Ledeboer brings the needle of a quadrant electrometer quickly to rest by making the quadrants of steel highly magnetized. The movement of the needle produces currents of induction and is dampened thereby. The suspension is unifilar.—*Nature*, Feb. 3, 1887, p. 331. J. T.

9. *Earth Currents.*—At a meeting of the Physical Society held in Berlin, Dec. 3, 1886, Dr. Weinstein gave some of the results of his observations on earth currents on the telegraph lines of the German Empire. The earth's currents showed a daily period with eight fluctuations, which did not occur through the whole year and were not constant in direction. These fluctuations were least in the morning between five and seven o'clock. The earth's current showed an intimate relation to the earth's magnetism and especially to the declination. The author found no relation between the earth's current and the sun's rotation, and also doubted the relation supposed to exist between the earth current and the earth's magnetism.—*Nature*, Feb. 3, 1887, p. 336.

J. T.

10. *Photography by Phosphorescence.*—In a recent number of the Scientific American, Dr. John Vansant gives an account of some experiments by him in taking photographs by the light radiated from a phosphorescent surface. A piece of paper coated with calcium sulphide and covered by a plate in which several letters were cut out, was exposed to the sunlight for two minutes. The light from the phosphorescent surface was sufficiently strong to make an image of the letters on a sheet of sensitive paper, developed in the usual way. A similar experiment with a photographic negative, placed upon a sheet of glass covered with the calcium sulphide which had been exposed to the sun several minutes, gave on the sensitive paper a good positive picture of

the negative; this was developed and fixed by the usual processes. Even when an interval of a number of hours had elapsed after the exposure, the light from the calcium sulphide surface was still intense enough to produce the effects described.

11. *The Coefficient of Viscosity of Air;* by HERBERT TOMLINSON.—In the previous experiments by the author on this subject the coefficient of viscosity of air was determined from observations of the logarithmic decrement of amplitude of a torsionally vibrating wire, the lower extremity of which was soldered to the center of a horizontal bar. From the bar were suspended vertically and at equal distances from the wire a pair of cylinders, or a pair of spheres. The distances of the cylinders or spheres from the wire were such that the *main* part of the loss of energy resulting from the friction of the air may be characterized as being due to the *pushing* of the air. A small part, however, of the whole logarithmic decrement was due to the rotation of the spheres or cylinders about their axes, and Professor Stokes has kindly added to the paper a note in which are deduced formulæ which serve to correct for this effect of rotation.

Acting on a suggestion of Professor Stokes, the author proceeded to determine the coefficient of viscosity of air by suspending a hollow paper cylinder about 2 feet in length and $\frac{1}{2}$ foot in diameter, so that its axis should coincide as to its direction with the axis of rotation. The cylinder was supported by a light hollow horizontal bar, about 7 inches in length, to the center of which the vertically suspended wire was soldered. The wire was set in torsional vibration, and the logarithmic decrement determined with the same precautions as before.

The mode of eliminating the effect of the internal friction of the metal wire, and also the effect of the air on the ends of the cylinder, is fully described in the paper.

The following were the results:—

Vibration-period in seconds.	Coefficient of viscosity of air, μ.	Temperature in degrees Centigrade.
3·6038	0·00017708	12·225
8·8656	0·00017783	13·075

In these experiments the loss of energy arising from the friction of the air may be characterized as being due to the *dragging* of the air, and it is very remarkable that there should be such close agreement in the values of μ as determined by this and the previous methods. The mean value of the coefficient of viscosity of air obtained by this method is 0·00017746 at a temperature of 12·650° C., and the mean value deduced from the previous experiments when proper correction has been made for the rotation of the spheres and cylinders about their axes is 0·00017711 at a temperature of 11·79° C. The above values of μ are given in C.G.S. units.—*Proc. Roy. Soc.*, No. 248.

12. *Note on Barus and Strouhal's paper on the Viscosity of Steel;* by W. F. BARRETT, Professor of Physics, Royal College

of Science; letter dated Dublin, March 1, 1887.—In Messrs. Barus and Strouhal's paper on the Viscosity of Steel, published in the January number of your Journal, the authors refer (p. 35) to the various physical changes which steel undergoes at a certain critical temperature. They do not seem to be aware of the investigations I have published on the "Molecular changes that accompany the Magnetization of Iron and Steel," for they refer to "Baur" (Wied. Ann., 1880) the disappearance of the magnetic state at the critical temperature. This fact they will find noticed in the report of a lecture of mine at the London Institution on April 23, 1873, published in the Journal of that institution in July, 1873; it was also mentioned in my papers in the Philosophical Magazine for December, 1873, and January, 1874. Messrs. Barus and Strouhal appear also to have overlooked the curious "after-glow" in steel wire, a discovery I made in September, 1873, and published in the Philosophical Magazine for December of that year. Perhaps you will allow me to state the main points in that paper, which are as follows: 1. Mr. Gore, in 1869, had discovered that a momentary *elongation* of iron occurred in cooling after heating a wire of that metal to a white heat. In 1872 I found a similar but reverse action took place in *heating* the wire. 2. This anomalous deportment was found both in heating and cooling to coincide with, on the one hand the *loss*, and on the other with the *resumption* of the magnetic state of iron or steel. 3. At the critical temperature the wire, having cooled down to a dull red heat, suddenly flashed into a bright glow; likewise during the *heating* of the wire the temperature remains stationary for a short time when the critical temperature is reached; a rise in the specific heat of wire and steel therefore occurs at the critical temperature. 4. A curious crepitation occurs at the critical temperature, similar to that heard in the magnetization of iron, or in the production of the scales of oxide on the wire. 5. Thermo-electric inversion occurs at this same temperature. 6. Hard iron wire and steel wire exhibit the phenomena but certain specimens of good soft iron failed to show it, and even in the wires that exhibit it the phenomenon grows less marked after repeated heating and cooling and finally disappear.

To these observations I may add that a recent investigation on the properties of manganese steel wire (Proc. Royal Dublin Society, December, 1886) shows that this body, which is almost a non-magnetic metal,* does *not* exhibit the anomalous deportment observed in ordinary steel wire. This fact is of considerable interest as linking the foregoing phenomena more closely with the magnetic state of iron and steel.

In conclusion, permit me to thank Messrs. Barus and Strouhal for their very carefully conducted and admirably devised series

* In the paper referred to I have shown that if the magnetic susceptibility of iron be 100,000, that of manganese steel is only 300, about the same as ferric oxide.

of experiments, and to express a hope that they will continue the work they have so excellently begun, stating, I hope in future, somewhat more fully the conclusions deduced from their formidable tables of experimental results.

II. Geology and Mineralogy.

1. *Eruption of Mauna Loa, Hawaii, in January.*—The recent eruption of Mauna Loa was like that of 1868 in being preceded by many earthquakes, though much less violent, and also in having its principal discharge in the Kahuku region, Southern Hawaii, and also nearly parallel in course, but situated two to four miles farther west and starting eight to ten farther north. The information here given with regard to it is from copies of the Pacific Commercial Advertiser and Hawaian Gazette of Honolulu, received from the Surveyor General, Mr. W. D. Alexander, and from a much reduced copy (photographic) of a large map of Hawaii made by the survey which has just gone to the engraver.

Mr. D. H. Hitchcock reports that from early in December last, earthquakes steadily increased in number and heaviness, and averaged three a day by the 12th of January. In Kahuku, according to Mr. George Jones, there were 314 shocks between 2^h 12′ A. M. of Jan. 17th and 4^h A. M. of the 18th, 67 between that time and midnight and 3 the following day, making 383 in all. Ten miles west, in Hilea, the number reported by Mr. C. N. Spencer between 2 A. M. of the 16th and 7 P. M. of the 18th is 618.

With the sudden increase in the earthquakes on the night following the 16th, there was an outbreak of fires on the summit of Mauna Loa, three or four miles northeast of the crater, near Pohaku o Hanalei; they disappeared after a few hours. Three hours after the cessation of the earthquakes at Kahuku, at 7 A. M., on the 18th, according to Mr. Jones, the outflow of lavas began in Kau, north of Kahuku, or was first known to be in progress. It came from a fissure, the highest point of which was about 6,500 feet above the sea, and about twenty miles from its terminus on the sea coast, which it reached about noon of the 19th, near Puuhue, nearly four miles west of the terminus in 1868. Mr. Spencer, who visited the point of chief outflow on the 20th, says that there were fifteen fountains of molten lava, the highest one rising to a height by estimate of about 200 feet. The stream flowed off bearing bowlders weighing tons, and with explosions at intervals sending up columns of smoke sometimes 500 feet high. He states that during the first 24 hours the rate of flow was only a mile and a half an hour, and the lava field made was of the a-a kind, rough clinkers; but on the 20th the flow was rapid and the lava of the smooth kind, or pahoehoe. No cinders or volcanic ashes were made along the coast or elsewhere. By noon of the 24th the flow had nearly stopped, though the fires were still active along the stream above. Mr. E. S. Bishop, who

was in the region on the 2d of February, states in a paper in Science, of March 4th, that the area of lava was mostly of the a-a kind, and that the stream extended out beyond the shores 300 to 500 feet, adding much to the island.

On the 23d, earthquakes began again and continued through the 24th. They were heavy enough at Kahuku to throw over walls and destroy or move some houses. Damage was done also at other places and to some extent at Hilo, where a heavy shock was felt near noon on the 23d and many others, but lighter, on that day and the next.

The oscillations at Hilo are stated to have been from S.S.E. to N.N.W. According to Mr. F. L. Clarke, of the Government Survey, the walls that fell in Kau had a northeast and southwest direction and were thrown to the southeast, and the houses (light wooden buildings) were moved 8 or 10 inches in the same direction or down the slopes. Mr. Severin, a photographer, accompanied Mr. Clarke to the region of the outflow and many photographs were taken.

A "heavy cloud of smoke, the heaviest ever seen there [by the writer] was resting over Mauna Loa all day Sunday and Monday, Jan. 23d and 24th;" and on the 25th the sun was scarcely visible on account of the smoky atmosphere. On the afternoon of that day a heavy storm of thunder and rain set in.

The paper of the 21st of February has a letter from Hilo, dated February 17th, announcing that at 8 A. M. of that day a dense volume of smoke extended from the summit crater eastward along the ridge of the mountain six or seven miles toward Kilauea, apparently indicating a summit outflow in that direction supplementing that in Kau.

The Hawaian Gazette of March 1st states that Mr. D. W. Hitchcock was on Mauna Loa, February 20th, and found vapors issuing from large fissures, nearly in a line with those of 1880, but no lava had reached the surface. Kilauea has been moderately active during this period of eruption, rather increasing in activity since it began, but without any show of special disturbance or sympathy.

2. *Volcanic Eruption in Niua-fu, Friendly Islands.*—Earthquakes began at Niua-fu on the 8th of June last, and occurred on the 11th, nearly cotemporaneously with the New Zealand eruption; and the outbreak occurred on the 31st of August, the date of the Charleston earthquake. The eruption continued for ten days and the chief destruction was produced by the finer cinder ejections; the stones thrown up "fell straight, or nearly straight, back." Two preceding eruptions occurred 19 and 40 years ago. —*From a letter of Mr. C. Trotter, F.R.G.S., in Nature of Dec.* 9, p. 127.

The volcanic line of Central New Zealand trends about N. 30° E., and, if followed northward with a small variation in direction, it passes along the Kermadec group and that of the Tonga or Friendly Islands, the variation being to N. 22° E. in the northern

part; moreover the body of New Zealand conforms in trend. The groups of islands having this nearly common course are parts of a great mountain system of the ocean, and of the one prominent system in the Pacific having a north-northeast direction. The length is 1,500 miles, reckoned from Central New Zealand, and over 2,000 from its southern end. The whole line may be viewed as having been, at the beginning and since, the course of a series of fractures, outflows and uplift, and in an important sense, a line of common genetic action and results. It is not improbable therefore that sympathy should appear between distant parts of the line, in fractures, earth-shocks and outflows.

The Friendly Islands and Charleston are nearly 100 degrees of longitude apart, and 50 degrees of latitude; and the approximate parallelism of trend in the mountain system of Eastern America and that of the New Zealand system in the Pacific, is hardly a sufficient reason for simultaneous earth-movements, unless the earth is working as a unit in its geographico-geological development. J. D. D.

3. *The Earthquake in Switzerland.*—Professor FOREL, the meteorologist, of Morges, on the Lake of Geneva, has just issued a report on the earthquake of February 23. He classifies the shocks under three heads—namely, preparatory shocks, strong shocks, and consecutive shocks. It is difficult, in the absence of trustworthy data, to indicate the precise locality of the first-named, but Switzerland was undoubtedly the region of the second; but it was to the third—that is, the consecutive shocks—that all the mischief was due. The professor traces the course of the phenomenon in Switzerland over a radius of at least four hundred square miles. Its force was greater in the southern parts of the country than in the north, though the shocks were felt throughout Geneva, Berne, Neuchâtel, Fribourg, Vaud, Valais, and Tessin; and observations go to prove that these shocks traveled almost due north and south, although the direction of the oscillations does not coincide with this course. The oscillations in Switzerland were characterized by their number and repetitions. In some localities they were longitudinal; that is, running parallel to the meridian; in others they were transverse, running or flowing from east to west. The vertical movements were marked by their feebleness where indicated, but in the greater part of the territory affected vertical oscillations were entirely absent. One of the peculiarities of the oscillations generally was the length of duration, which is set down as varying from 10 to 30 seconds. But the collected reports prove that the mean of these figures more nearly represents the prevailing duration. The intensity of the shocks was greater in the central and southern areas of the disturbance, and it would seem as if the shocks only just failed to attain the necessary strength which would have produced disastrous effects. As it was, church bells were rung, in some places violently; windows were rattled, doors thrown open, ceilings slightly cracked, and morsels of plaster

were brought down, and here and there stacks of wood were thrown over. One of the most striking features of the phenomenon was the extraordinarily large number of clocks that were instantly stopped, and this fact has afforded the best possible means of determining with something like perfect accuracy the time of the shocks, which varies from three to four minutes past six in the morning, Berne time. The large astronomical clock of the Observatory at Basle stopped exactly at 6h. 4m. 7s. This, taken as representing Berne time, corresponds with 5h. 43m. 35s. of Paris, 5h. 55m. 43s. of Marseilles, 6h. 3m. 2s. of Nice, and 6h. 24m. 3s. of Rome.

The consecutive shocks, which were responsible for all the loss of life and damage to property, were centralized in the region of the Riviera. The greatest damage was done by the first two shocks, which occurred with an interval of fifteen minutes between them. The reports from the Swiss observatories also show that a series of feebler shocks were experienced in Switzerland later on in the same day, and also on several succeeding days.—*Nature*, March 10, No. 906.

4. *Earthquakes of Andalusia on the 25th of December*, 1884. (Atti R. Accad. d. Lincei, iii, Roma, 1886.)—Messrs. T. Taramelli and G. Mercalli have made a thorough study of the Andalusian earthquakes of 1884, and published a very valuable memoir on the subject, illustrated by geological and seismic maps. It is in three parts. The first treating of the orographic and geological constitution of Andalusia and the Province of Almeria; the second, a relation of the facts in order of occurrence and the general conclusions from these and those of other earthquakes in Spain; the third, a review of the facts with reference to the isoseismic zones, the position and form of the seismic vertical or epicentrum, the velocity of propagation, the depth of the centre, intensity of the shocks, the dynamical effects as exemplified in the condition of buildings; also the consideration of the subsequent shocks until January, 1886, comparisons with those of other seismic areas of the Mediterranean basin, the nature and cause of the Andalusian earthquakes, and relation to other volcanic centers.

In the second part, the following important conclusions are deduced:

1. Earthquakes are much more frequent in the littoral region than in the interior of Spain, and more frequent in the southern than in the northern.

2. The topographic and chronological distribution of the earthquakes reveals the fact that there are several localized seismic centers in Spain, distinct and independent in their movements, yet not without reciprocal influence.

3. Considering the chronological distribution of the earthquakes in the different Iberian regions, the seismic activity, as regards its more energetic manifestations, is transferred from one region to another at long intervals of time.

4. A fact very characteristic of the earthquakes of Southern

Spain is the great number of minor shocks which usually follow, and which at times also precede the maximum shock of each seismic period; but in these seismic periods the position of the maximum shock of the period with respect to the others is not constant. In general the period opens with the maximum shock, yet with some preceding small shocks; then follow many minor shocks; then, after a few months, a second seismic period commences in the same area which begins with a shock that is even heavier than the maximum of the first period and is preceded sometimes also by small shocks.

5. Considering the chronological distribution of earthquakes in a given region, or in the whole peninsula, no periodical return of the maxima is made out, neither decennial nor of any other period; but there is a certain approximately secular return, bisecular or trisecular.

6. As regards the seasons, the greater number of earthquakes in Spain occur in the autumn and winter, as compared with the summer and spring.

The able discussion leads the authors to the following general conclusions:

The great earthquake of 1884 shook an area not volcanic, but one that was in line with the perimeter of the Mediterranean basin, with the volcanic and seismic zone of Southern Italy, Greece, Asia Minor, etc.; and should be classified therefore with the perimetric earthquakes, of so frequent occurrence in Southern Italy. The seismic movement radiated from a center of ellipsoidal form, at a depth of 12 or 13 kilometers, and was thence propagated in the earth's crust according to the fundamental laws of molecular movement in solids. The seismic wave was deviated by refraction, and especially by reflexion, in traversing rocks of different density and elasticity.

The velocity of transmission could not be determined; yet it is made evident that in all directions the rate was less than the propagation of sound in the earth's crust.

The seismic wave was propagated most easily and uniformly, and with relatively less destruction, in the compact crystalline rocks of the Archæan and Paleozoic. The general direction of the bedding favors transmission of the seismic movement propagated parallel to it, and is an obstacle to movement in a transverse direction.

The seismic movement in passing from the more compact and relatively elastic Archæan and Paleozoic rocks to a region of marls, clays, travertine and the like is transformed into movement of mass, producing more disastrous effects the less the compactness, continuity and homogeneity of the superficial beds.

The intensity of the Andalusian earthquakes of 1884 at the center was greater than that of the Neapolitan of 1857, the Ischian of 1883, etc.; but it reached the surface with less energy, producing less disastrous effects in proportion to the greater depth of the center and the greater width of the shaken area. Yet the

disastrous effects became somewhat increased in the mountainous country, owing especially to the miserable construction of the houses and their sites on the edges of crumbling precipices, or on steep declivities.

The effects at the surface consisted in the opening of cracks, slipping of the surface material, especially the Tertiary and Quaternary, and in temporary and permanent changes of level upward and downward.

The first shock was preceded and accompanied by low barometric pressure and followed by abundant rain, with lightning and other atmospheric electrical phenomena.

The Andalusian seismic period, begun in 1884, and probably not yet ended, is referable to the same seismic heat-center which caused the disastrous earthquakes of Malaga in 1581 and 1680, for these were wholly similar to the recent earthquake in area and center of movement.

5. *Holocrystalline granitic structure in eruptive rocks of Tertiary age.*—As is well known, the age-classification of massive rocks has, within the last few years, been largely invalidated by the discovery of several localities where Tertiary surface rocks of the ordinary type pass gradually into coarsely crystalline, granitoid varieties as they are traced downward. The "Nevadite" of von Richthofen, although shown by Hague and Iddings to contain some glassy base, is essentially a granitoid dacite. The investigations of Hague and Iddings at the Comstock lode; of Judd on the tertiary peridotites and gabbros of the western coast of Scotland; and of Lotti on similar rocks in northern Italy, conclusively prove that the physical conditions under which a rock mass solidifies, and not the geological *time* of its solidification, determine its structure. Coarsely granular rocks are more abundant in earlier formations because their superficial equivalents have been removed by erosion, while in the younger deposits there has been no time for this and hence the coarser rocks are mostly still deeply buried. Only as expressing this fact, is the age-classification of massive rocks now to be considered as useful.

A very important contribution has recently been made to this interesting subject by Professor Alfred Stelzner of Freiberg, in his newly published volume on the Geology of the Argentine Republic. (Beiträge zur Geologie und Paläontologie der Argentinischen Republik. I. Geologischen Theil. 4°. Cassel und Berlin, 1885, pp. 329, with a colored geological map and three sheets of profiles.) This work contains the results of the scientific expeditions made in the region of the Andes by the author during his residence as professor in the National University at Cordova, between the years 1871 and 1874. It is filled with valuable observations relating to all the geological formations encountered and contains detailed petrographical descriptions of the massive rocks. It is, however, to the contents of chapters xviii and xix (pp. 198–213) which relate to the Tertiary Eruptive Rocks with a granitic habit, that it is desired to call particular attention.

In the heart of the South American Cordilleras, almost on the boundary between Chili and the Argentine Republic, northeast of Santiago, the author met four different localities where typical granitic and dioritic rocks occur in the midst of the prevailing andesitic lavas, tuffs and breccias. One of these is in the San Antonio, and three in the Juncal valley, which penetrate the mountains in a northeastward and eastward direction from San Felipe. These localities were seen by Darwin, who described the rock under the name of "*andesitic granite*" in his Geological Observations in South America. (London, 1846.)

Professor Stelzner concludes that from a purely petrographical standpoint these rocks are totally distinct from the andesites, and are in no way to be distinguished from the most typical Archæan granites and diorites. From a study of their field relations, however, he finds that they are undoubtedly the *youngest* rocks of the region, breaking through and sending apophyses into the andesite tuffs and accompanying sediments. To reconcile these two facts, he assumes that they are late-Mesozoic or Tertiary eruptive masses which have slowly solidified under conditions of high pressure and temperature. Inasmuch as Darwin's descriptions of these "*andesitic rocks*" laid specific stress upon their recent formation, the author proposes to reserve this term (Andengesteine" for granitic rocks of tertiary age; and speaks of "Andengranit" (andesitic granite), "Andensyenit" (andesitic syenite), "Andendiorit" (andesitic diorite), etc.

Many other descriptions are quoted from Darwin, Stübel, E. Williams, Clarence King and Zirkel, which indicate the occurrence of similar rocks at many localities in the Cordilleras of both North and South America.

In urging a more careful examination of these rocks in future, Professor Stelzner expresses the following opinion, with which geologists the world over are daily becoming more and more willing to agree. "Sie (die Andengesteine) werden uns, wie ich meinerseits glaube, immer mehr und mehr erkennen lassen, dass die grössere oder geringere Krystallinität eruptiver Gesteine keineswegs, wie man so lange und so hartnäckig behauptet hat, von der Alter der letzteren abhängig ist, sondern lediglich von den physikalischen Umständen, unter denen die mineralische Differenzirung und Erkaltung der gluthflüssigen Magmen vor sich ging." GEO. H. WILLIAMS.

6. *Report for* 1885, *Geological Survey of Canada;* A. R. C. SELWYN, Director.—This volume contains reports of much valuable geological work. A few facts are here cited. Mr. Selwyn states, in his review of the work of 1885, that Mr. Ells has been investigating Quebec, north of Vermont, New Hampshire and Maine; and besides mapping the Silurian area, which in part includes metamorphic rocks, has found, from the intimate connection between the altered Silurian slates and associated granites, that the granites are, "as in New Brunswick, probably Devonian."

In the report on New Brunswick, by Mr. CHALMERS, it is stated

that the marine seashore beds, the Leda clay and the overlying Saxicava sand, occur around the Baie des Chaleurs basin, having a maximum thickness above the sea level west of Bathurst harbor of 125 to 135 feet (75 + 50 or 60); in the Restigouche estuary, the Saxicava sand is 150 feet thick; and in St. Ann Settlement the sand reaches an elevation of 150 to 175 feet. In the Bay of Fundy, the same two strata occur nowhere above 200 feet; on pp. 42, 43, GG, a list of the fossils is given. Mr. Chalmers also treats in detail of the drift, and has a long table of directions of glacial scratches.

Mr. George M. Dawson has a preliminary report on the Physical and Geological Features of the Rocky Mountains between latitudes 49° and 51° 30′ north of the headwaters of the Missouri. The Rocky Mountain region, or the Western Cordillera belt, becomes narrowed and runs to the 56th parallel with an average width of about 400 miles. It comprises four parallel ranges, (1) the Rocky Mountains proper, (2) the Gold ranges (next west), (3) the Coast Range, as a continuation of the Cascade Mountains of Oregon and Washington Territory; (4) the Island Range including Vancouver and the Queen Charlotte Islands, outside of which the ocean bottom sinks rapidly to abyssal depths. Between the 2d and 3d of these ranges lies the Interior Plateau of British Columbia, averaging 100 miles in width, and 3500 feet in mean elevation above the sea. The Rocky Mountains proper, about 50 miles wide, and N.N.W. in mean trend, have a well-defined valley on the west, occupied by the Columbia, Kootanie and other rivers, and known to preserve its general direction and character for over 600 miles. The eastern base is about 4360 feet above tide level, the valley on the west 2450 feet. The Cretaceous and Laramie rocks, much upturned for a breadth of 15 miles, make the eastern foot hills. The rocks of the range are folded or upturned and consist chiefly of Cambrian, Devonian and Carboniferous strata; and the folding in some parts continues into the Cretaceous on the east. The highest summits, the culminating region of the Rocky Mountains, are found about the 52d parallel, and between this and the 53d, Mount Brown and Mount Murchison occur with reputed altitudes of 16,000 and 13,500 feet. These are a few facts from the earlier part of Mr. Dawson's report.

Mr. Ch. Hoffman mentions the occurrence at Aldfield, Pontiac Co., Quebec, of the mineral molybdenite in large crystals, one of the less perfect weighing very nearly 2½ pounds, and a very perfect tabular hexagonal prism measuring five centimeters across, or about two inches.

7. *Mineral Resources of the United States, Calendar year* 1885. 576 pp. 8vo. Washington, 1886. — This volume, the third of the series, contains like its predecessors, a large amount of valuable and interesting information upon the mining industries of the United States. The preparation of the volume has been accomplished in part by Mr. Albert Williams, Jr., the former editor, and in part by Mr. David T. Day. A fourth report for

1886 is promised early in 1887; the value of the series increases with each additional volume because of the opportunity thus offered for study and comparison together of the facts presented in the succeeding years.

8. *Geological Collections: Mineralogy;* by W. O. CROSBY, Assistant. 184 pp. Boston, 1886.—This is a well prepared guide to the mineralogical collection of the Boston Society of Natural History; the general chapters forming the introduction give it something more than a local interest and value.

III. BOTANY AND ZOOLOGY.

BOTANICAL NOTES.—*Entomophilous Flowers in Arctic regions.* In the *Botanisk Tidsskrift*, (with its French title of *Journal de Botanique*), published by the Botanical Society of Copenhagen (which Journal is now in its sixteenth volume), Professor Warming has published a series of articles mainly concerning the adaptations of entomophilous flowers in an arctic district of scanty insect life. His interesting biological notes are illustrated by figures interspersed in the letter press, and the whole is happily made available to us by a French *résumé* of the Danish text, a most commendable feature. These papers comprise the results of Dr. Warming's observations in Greenland in the summer of 1884 and a comparative series in Arctic Norway in 1885. Greenland is very poor in insects, especially of insects which perform an important part in the fertilization of the entomophilous blossoms of northern regions generally. Dr. Warming undertook a careful comparative study of these northern flowers, to learn whether those in Greenland were identical in floral biology with the same species in Europe. In many no differences were found, but in not a few certain modifications were detected in the Greenland flowers which rendered them more adapted to self-fertilization than those of the same species on the European continent, where the appropriate visiting insects are more abundant. In answer to the question whether the attractiveness of these blossoms for insects remained unaltered in Greenland, Dr. Warming is able to state that with three or four exceptions, the nectar-secretions seemed not to be diminished; but that the odors were feebler, the size of corolla less, and the colors not so vivid as in the same species on the continent. As the entomophilous flowers of Greenland manifest an increased adaptation to self-fertilization, it might have been expected that the diœcious or polygamous tendency of some of them would disappear, but it proved not to be so. But the Salices were found to be remarkably fruitful, and it seems that they had become anemophilous.

Fascicles 98 and 99 of the *Flora Brasiliensis* have appeared. In the former Dr. Schumann gives the Brazilian *Tiliaceæ* and *Bombaceæ*. In the other Professor Cogniaux continues the elaboration of the large order *Melastomaceæ*.

In vol. vi, part 3, of Hooker's Icones Plantarum, issued in February, one North American species is figured, *Cotyledon viscida*,

S. Watson, collected in Southern California by the Rev. Mr. Nevin. There is also *Anemone Henryi*, of Oliver, from Central China, a true *Hepatica*, with round-cordate leaves crenate-lobulate, but yellow-flowered. The ovaries are figured with a terminal stigma; but that is probably not quite right.

Sir Joseph Hooker has edited and brought out the fifth edition of that most popular book, Bentham's *Handbook of the British Flora* (Reeve & Co.), in the same form as the fourth, but condensed into rather fewer pages, the specific names and characters being brought into one paragraph. This condensation has enabled the editor to incorporate a good many notes and needful alterations, and some few recently added species, in all respects following the author's lines. Botanists will be glad to have this characteristic work kept up.

Professor Volney Rattan, of the San Francisco High School for Girls, has brought out an *Analytical Key to West Coast Botany*, "containing descriptions of sixteen hundred species of flowering plants, growing west of the Sierra Nevada and Cascade crests, from San Diego to Puget Sound," in 128 pages. It should be helpful to students.

Mr. Thomas Howell, of Arthur, Oregon, has issued a *Catalogue of the Known Plants of Oregon, Washington and Idaho*, down to and including the Pteridophytes, pp. 28, 8vo.

Dr. T. F. Wood and Gerald McCarthy have brought out a *Wilmington Flora, a List of Plants growing about Wilmington, North Carolina, with date of Flowering.* A map of the county is annexed. It is published by the Elisha Mitchell Scientific Society. The district is of peculiar interest.

The California State Board of Forestry has issued its First Biennial Report, pp. 252, with maps. There are reports on the forests of the most southern counties, by the chairman of the State Board, Mr. Kinney; on those of the Sierra-district farther north, by Mr. Wagner; on the trees and shrubs of San Diego Co., by C. R. Orcutt; and a detailed and important one on the Redwood, by the engineer, Mr. Vischer, with a supplement relating to the quantity of standing timber other than Redwood.

Dr. Arthur, the Botanist to the New York Agricultural Experiment Station, communicates his Report for the year 1885 and also that of 1887. In both the pear-blight is treated at large; also the rotting of tomatoes, of cherries and plums, the plum-leaf fungus, the mildew of strawberries, lettuce, etc., and several illustrations are given in the letter press; those of the earlier report are neat and well printed.

A small supplementary fasciculus now completes the second volume of Dr. Beccaris' *Malesia*, with very full indexes of the two volumes, both of names and subjects.

Sympetaleia, Gray, Proc. Am. Acad. xii, 161, is an anomalous gamopetalous genus of Loasaceæ, of which Dr. Streets collected a solitary specimen in Lower California at Pulpito Point. As it was published in the same year with the first volume of the Genera Plantarum (1877), it was not there taken up, and conse-

quently does not appear in that work. So Professor Baillon was not aware of it when, in January last, he published the same singular genus (in Bull. Soc. Linn. Paris, no. 82, p. 660) under the name of *Loasella*, with some interesting remarks. He found a specimen in the Mexican herbarium of M. Thiebault, who collected it long ago, at Guaymas, which is on the Mexican side of the Gulf of California, almost opposite Cape Pulpito. The characters of *Sympetaleia aurea* are exactly those of Baillon's *Loasella rupestris*, except that the corolla-lobes of the latter were thought to be "perhaps valvate," whereas we found them to be imbricate in the bud.

Index to Plant-Names.—It is generally known to botanists that Mr. Darwin—wishing to supply to this generation an advantage which he had experienced the want of himself—provided the means of preparing and publishing, under the superintendence of the Director of Kew Gardens, a new and complete *Index of Phanerogamous Plant-Names*. The formidable task has been assigned to Mr. Daydon-Jackson, one of the secretaries of the Linnean Society, who is particularly well versed in botanical bibliography, and to a number of assistants. Their work was commenced five years ago. The editor now publishes, in the Journal of Botany, British and Foreign, for March, the first portion of a report of progress, in which the plan adopted is to a certain extent explained. The work was at first intended to be a kind of new edition of Steudel's Nomenclator, based systematically on Bentham and Hooker's Genera Plantarum; but it was soon determined that the names should be followed by references, and that in other respects it would have to be constructed upon original lines. We judge that this great undertaking has been most carefully planned as to system and details. Two or three condensed extracts from this report suffice for noting certain points.

"Our starting-point, then, is the publication of Linnæus's first edition of the Systema, in 1735, which he followed up by the Genera, in 1737. . . . Where Linnæus ascribes the genus to an earlier author, we say 'Tourn. ex Linn.,' etc., but do not refer directly to pre-Linnean literature." This is well.

"The first edition of the Species Plantarum was issued in 1753, and that we must regard as the introduction of *nomina trivialia*." So we shall have the earlier Linnean species cited correctly, and not from a later edition. The same, no doubt, of genera.

"Robert Brown published a genus as *Eleocharis*, which Lestihedris altered to *Heleocharis*, as more accordant with the Greek, an alteration adopted by many subsequent writers, who nevertheless employ Beauvois's *Oplismenus*, which is equally faulty, without a sign of reprobation." Whatever small emendations of a name may be allowed, it will never do to change the initial letter for the sake of classicalness.

"While on the subject of fixity of name, I would remark that our practice is to take the name under which any given plant is placed in its true genus as the name to be kept up, even though the author may have ignored the proper rule of retaining

the specific name when transposing it from the old genus to the new, when at least that name is not already in the genus receiving the accession. Wantonly to set aside the joint name thus given, and to publish a new name by joining the oldest specific to the true generic, is a mischievous practice which should never be condoned; it is adding to the already vast mass of useless synonyms, and is more likely the offspring of vanity than of a sincere desire to promote science." This is putting the case a little more decidedly than Bentham did, but not too strongly; for it follows implicitly from the principle of the accepted rules.

The re-paging of separate memoirs extracted or reprinted from serial or other works is justly deprecated; and the American Academy of Arts and Sciences is mentioned as an example to be followed. This Academy absolutely forbids all tampering with the original pagination. A. G.

2. *Gilded Chrysalides;* by EDWARD B. POULTON, Esq. (Roy. Inst. Gt. Britain.)—Mr. T. W. Wood in 1867 published the observation that certain pupæ (*Pieris brassicæ*, *P. rapæ*, &c.) resemble in color the surface on which they are found. Although this was disputed by some naturalists, it was confirmed by Mr. A. G. Butler and Prof. Meldola. In 1874 Mrs. M. E. Barber published some very striking observations on the colors of the pupa of *Papilio nireus* (South Africa) confirmation being afterwards afforded by Mr. Trimen, from the case of *Papilio demoleus*. Dr. Fritz Müller, however, shows that *Papilio polydamus* is not sensitive to surrounding colors. The observations were explained by supposing the moist skin of the freshly formed pupa to be "photographically sensitive" to the color of surrounding surfaces; but Prof. Meldola pointed out that there can be no real analogy with photography. Furthermore, many pupæ are formed at night when the surrounding surfaces are dark. The present investigation was undertaken with the belief that the influence would be found to work upon the larva as it rests upon some colored surface before pupation.

I. *Experiments upon Vanessa Io.*—This pupa appears in two varieties, being commonly dark gray and much more rarely yellowish-green. Six larvæ placed in a glass cylinder covered with green tissue paper, produced six green pupæ; one of these transferred to a black surface while still moist and fresh, became a green pupa precisely like the others.

II. *Experiments upon Vanessa urticæ.*—The pupæ have no green form, but appear in many shades of dark gray, the lighter ones having golden spots on them, while the extreme forms are almost covered with the golden appearance. These latter are very rarely seen in nature, except when the pupa is diseased. Over 700 pupæ were obtained in the following experiments:—

(1.) *Effects of Colors.*—*Green* and *orange* surroundings caused no effect on the pupal colors; *black* produced, as a rule, dark pupæ; *white* produced light pupæ, many of them being brilliantly golden. This last result suggested the use of *gilt* surroundings,

which were found to be more efficient than white, and produced pupæ with a color which even more resembled gold.

(2.) *Mutual Proximity.*—The larvæ being dark, it was found that when many of them became pupæ on a limited (white or gilt) area, the pupæ were darker than when they had been more isolated. The colors of each were in fact affected by that part of the surroundings made up by the black skins of its neighbors.

(3.) *Illumination.* — Black surroundings produced rather stronger effects in darkness than in light, but the pupæ were dark in both cases.

(4.) *Time of Susceptibility.*—The mature larvæ, after ceasing to feed, wander (stage i) until they find a surface on which to pupate; they then rest upon it (stage ii), and finally hang, head downward, suspended by their last pair of claspers (stage iii), in which position pupation takes place. Stage i is variable in length, stage ii may be estimated at 15 hours (but it is also variable), while stage iii is fairly constant, and lasts about 18 hours; while the whole period is commonly about 36 hours in length. The larvæ are probably affected by surrounding colors for about 20 hours, before the last 12 hours of the whole period, and in this time the pupal colors are determined. These facts were discovered by a very large number of experiments, in which larvæ were placed in surroundings of one color, and then after a variable time were transferred to another color producing an opposite effect. It was thus found that stage ii is more sensitive than stage iii, although there is some susceptibility during the latter stage.

(5.) *The Part of the Larvæ which is Sensitive to Color.*

(*a*) *The Ocelli.*—The most obvious suggestion was that the larval eyes (or ocelli, six on each side of the head) saw the colors, and being influenced, transmitted an impulse to the nervous centres which regulate the formation of the pupal colors. When, however, these organs were covered with black varnish, the pupæ resembled surrounding surfaces to the same extent as when they were produced from normal larvæ.

(*β*) *The Complex Branching Spines.*—It seemed possible that these structures might contain some organ which was influenced by the color, but after cutting them off, the larvæ remained normally sensitive.

(*γ*) *The General Surface of the Skin.*—This was tested by *conflicting color experiments.* It had been previously shown that the larvæ were sensitive during stage iii, and therefore they were covered in this stage with compartmented tubes, so constructed that the head and anterior part of the body hung in the lower chamber of one color, while the posterior part of the body was in the upper chamber in another color. In another method, the larvæ were hung upon a vertical surface, while the head and front part of the body passed through a hole in a shelf, the vertical surface above the shelf, and the upper side of the shelf itself being one color, while the vertical surface below the shelf and the lower side of the shelf were of the color tending to produce

the most opposite effects. The result of all these experiments was to show that the color influence does act on some element of the larval skin, and that the larger the area of skin exposed to any one color the more does the pupa follow its influence. Parti-colored pupæ were not obtained, thus probably pointing toward the action of the nervous system rather than toward the direct action of light on or through the skin itself.

(6.) *The Nature of the effects produced.*—The coloring matter of the dark pupæ is contained in a thin superficial layer of the cuticle; below this is a thicker layer divided into exceedingly delicate lamellæ between which fluids are present, and the latter form the thin plates which, by causing interference of light, produce the brilliant metallic appearance. The thinner upper layer being dark, acts as a screen in the dark pupæ. Precisely the same metallic appearances are caused by the films of air between the thin plates of glass which are formed on the surface of bottles long exposed to earth and moisture. Both have the same spectroscopic characters and the same transmitted colors (complementary to those seen by reflection). The brilliancy of the cuticle can be preserved in spirit for any length of time; it disappears on drying, but can be renewed on wetting (this had been previously known), and the colors are seen to change during the process of drying, and when the cuticle is pressed, for the films are thus made thinner. The same lamellated layer exists in non-metallic pupæ, and is used as a reflector for transparent coloring matter contained in its outer lamellæ. Thus the structure which rendered possible the brilliant effects due to interference, probably existed long before these special effects were obtained, and was used for a different purpose.

(7.) *The Biological Value of the Gilded Appearance.*—It is probable that the gilded pupæ of Vanessidæ resemble glittering minerals such as mica (which is very common in many places); their shape is very angular, and like that of minerals: conversely the gray pupæ resemble gray and weathered rock-surfaces, and the two conditions of rock would themselves act as a stimulus for the production of pupæ of corresponding color. The power was probably gained in some dry hot country, where mineral surfaces do not weather quickly. Once formed it may be used for other purposes, and in certain species is probably a warning to the enemies that the insect is inedible. It is interesting to note how the Vanessidæ, primarily colored so as to resemble mineral surroundings, are modified for pupation on plants. Thus *Vanessa Io* has a green form which is produced among leaves; *V. atalanta* has no green form, and spins together the leaves for concealment, but both these species commonly pupate freely exposed on mineral surfaces; *V. urticæ* has neither the green form nor the habit, and it has a strong disinclination to pupate on its food plant, as many observations concurred in proving.

III. *Experiments upon Vanessa atalanta.*—This species was also made brilliantly golden or dark-colored by the use of appropriate surroundings in the larval condition.

IV. *Experiments upon Papilio machaon.*—This species, like *P. polydamus* (Fritz Müller) has no power of being influenced by surrounding colors. A brown pupa was obtained on the food-plant, and many green ones upon brown twigs, &c. It is probable that less healthy and smaller larvæ often produce the brown form, just as diseased Vanessa larvæ produce gilded pupæ.

V. *Experiments upon Pieris brassicæ and P. rapæ.*

(1.) *Effects of Colors.*—*Black* produced dark pupæ, and the greater the illumination the darker the pupæ (*P. rapæ*), this result being the reverse of that obtained with *V. urticæ; white* produced light pupæ, and the greater the illumination the lighter the pupæ (*P. rapæ*); *dark red* (*P. brassicæ*) produced dark pupæ; *deep orange*, in both species, produced very light pupæ of a green color; *pale yellow* and *yellowish-green* produced rather darker pupæ than the orange; *bluish-green* produced much darker pupæ, while *dark blue* produced still darker pupæ (*P. rapæ* only). Hence there is a remarkable and sudden fall, followed by a slow and gradual rise in the amount of pigment formed as the light from various parts of the spectrum from red to blue predominates in the reflected rays which fall on the larval surface. But their effects on the formation of superficially placed dark pigment are accompanied by changes affecting the formation of greens and yellows, &c., in the deeper subcuticular tissues. Hence the results of any given stimulus are exceedingly complicated.

(2.) *Other Experiments.*—It was shown by the method described above that the ocelli are not sensitive in this species, and by similar transference experiments it was proved that the influence acts on the larva and not on the pupa itself.

VI. *Experiments upon Ephyra pendularia.*—In this genus of moths the exposed pupæ are often green and brown in different individuals, but these colors follow the corresponding tints of the larvæ, and therefore cannot be influenced unless the latter themselves were changed, and such susceptibility in the larval state has not been proved for this genus. This is the only known instance of a constant relation between the larval and pupal colors.

VII. *Experiments upon the Cocoon of Saturnia carpini.*—It was found that the larvæ spin dark cocoons in black surroundings, but white ones in lighter surroundings.

IV. Astronomy and Mathematics.

1. *The form of the area in the heavens from which the Meteors of Nov.* 27, 1885, *appeared to radiate.*—Mr. Ranyard in the Monthly Notices of the R. Ast. Soc. has discussed the evidence from observations by himself, Captain Tupman, Professor Young, M. Perrotin, and M. Thallon concluding that "there therefore appears to be some very definite evidence that the paths of these meteors did radiate from an elongated area with its axis north and south." Mr. Ranyard further says, "in order to account for the elliptic area, on the assumption that the deflection from the

original path takes place within the earth's atmosphere, it is necessary to find some cause which would account for the deflection being greater in one plane than in the direction at right angles to it. This would be the case if there were some arrangement of the particles in space which caused them to set themselves with their longer axes north and south. I would suggest that if the particles are magnetic they would, on coming up to the earth, tend to arrange themselves with their longer axes parallel to the earth's magnetic axis."

2. *The Boyden Fund.*—By the will of the late URIAH A. BOYDEN, property, the present value of which exceeds two hundred and thirty thousand dollars, was left in trust for the purpose of astronomical research "at such an elevation as to be free, so far as practicable, from the impediments to accurate observations which occur in the observatories now existing, owing to atmospheric influences."

The Trustees of this fund have transferred the property to the President and Fellows of Harvard College, in order that the researches proposed by Mr. Boyden may be directed at the Harvard College Observatory. These researches will be supported by a portion of the means of the Observatory, in addition to the trust fund itself. Professor Pickering has issued a circular requesting information with regard to the altitude, accessibility, and climate of various mountainous regions which might naturally be selected as suitable places for the proposed observations.

A location in the southern hemisphere will be preferable for various reasons. The southern stars invisible in Europe and the United States have been less observed than the northern stars, and by the aid of a southern station the investigations undertaken at Cambridge can be extended upon a uniform system to all parts of the sky.

3. *A Treatise on Algebra;* by Professors OLIVER, WAIT and JONES, of Cornell University.—This work was undertaken as a text book, and was developed, as the authors inform us in the preface, with the wants of their classes ever before them. But it grew beyond a manual; it is a treatise. It departs from the traditional forms of development of algebra in the arrangement of the subject, in the notations employed, in the forms of demonstration, and by introducing at an early stage the extensions of meaning of terms and processes required in higher algebra.

Experience in the class-room will show whether selections from this original and thoughtful work can be successfully used in elementary teaching. But the advanced student and the teacher will surely find in it an abundance of helpful ideas and methods. There is one serious deficiency, it has no alphabetic index.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Scientific Writings of Joseph Henry.* Vols. i and ii, pp. 523 and 559 large 8vo. Washington, 1886. Published by the Smithsonian Institution.—The contributions to science by Profes-

sor Henry, extending as they did over more than half a century, played so important a part in the development of science in this country that it is well, alike for the reputation of their author as for the interests of the worker of to-day in the same fields, that they should be collected and given to the world in convenient form. This is especially true in view of the fact that the original papers were much scattered and many of them are now hardly accessible. The collection is published by the Institution of which he was Director for more than thirty years, and to which he devoted a large part of his life's energies. The first volume contains the greater part of the papers on physical subjects, extending from 1824 to 1855, with also the acoustical researches of 1874 to 1877. The second volume is largely occupied with the more popular Meteorological Essays, with also papers on some other kindred subjects; the volume closes with the addresses to the National Academy of Sciences in April, 1878. The life of Professor Henry was conspicuously active and productive, and his original contributions to Physical Science, particularly in the branch of electro-magnetism, have given him a place he will always hold in the foremost rank of American workers.

2. *The American Naturalist.*—The American Naturalist will be in future published by the house of J. B. Lippincott & Co. of Philadelphia, under a slight change of editorial management. Dr. Packard retires, and Dr. J. S. Kingsley becomes with Professor Cope assistant editor-in-chief. The remainder of the editorial corps continues as before, excepting the addition of Professor J. H. Comstock of Cornell University, who will have charge of the Entomological Department. As stated on its title-page it is "A Monthly Journal devoted to the Natural Sciences in their widest sense," and, we add, value to all interested in its departments.

3. *Van Nostrand's Science Series.*—Recent issues of this series are No. 90, Analysis of Rotary Motion as applied to the Gyroscope by Major J. G. Barnard, a reprint of the well-known paper first published in 1858 in the Journal of Education. Also, No. 91, Leveling, barometric, trigonometric and spirit by Ira O. Baker; this gives a clear and simple statement of the methods applied to the determination of altitudes.

OBITUARY.

John Arthur Phillips, F.R.S.—Mr. Phillips, the distinguished author of works on Ores, Mining and Metallurgy and of papers on petrography, died on the 5th of January, in his 60th year. He was engaged, at the time of his death, on a new edition of his work on "Metallurgy," in conjunction with Mr. Bauerman. In connection with his study of gold deposits he visited the gold regions of California in 1861 when he made observations of much interest on the formation of veins. "Nature," of January 13th, closes a notice of Mr. Phillips with the words: "He was a large-hearted and open-handed man, fond of taking every chance that came in his way of doing a good deed and helping any one to whom his help could be of service."

APPENDIX.

ARTICLE XXXV.—*American Jurassic Mammals;* by Professor O. C. MARSH. (With Plates VII, VIII, IX, and X.)

IN previous numbers of this Journal, the writer has announced the discovery of Jurassic Mammals in this country, and has given brief descriptions of the more important forms brought to light.* Since the last article on this subject, a large amount of new material has been secured, including representatives of several hundred individuals. The remains consist not of lower jaws alone, but of various portions of the skull, and not a few vertebræ, limb bones, and other parts of the skeleton.

These fossils, although fragmentary, are usually well preserved, but owing to the peculiar conditions under which they were entombed, no two bones of the skeleton are as a rule found together. This fact, taken in connection with the very diminutive size of the animals themselves, and especially with the present brittle nature of the teeth and jaws, has rendered their investigation a work of great difficulty. The importance of the subject, however, and the fact that all the known remains of mammals from the Jurassic of this country are in the collection made by the writer, have led to a careful study of the whole material, and the results will be brought together in a Memoir now in preparation for the United States Geological Survey.

Some of the results of this investigation, and notices of several new forms recently discovered, are given below in the present article.

* This Journal, vol. xv, p. 459, 1878; vol. xviii, pp. 60, 215, and 396, 1879; vol. xx, p. 235, 1880; and vol. xxi, p. 511, 1881. See, also, Proceedings British Association, Montreal Meeting, p. 734, 1884.

In connection with this work, the writer has also examined the more important specimens from the Jurassic of Europe, and, likewise, the few specimens known from the Trias, in both Europe and this country.

The American Jurassic Mammals hitherto found are all from essentially the same geological horizon, in the Atlantosaurus beds, of the Upper Jurassic. The principal locality is in Wyoming, on the western slope of the Rocky Mountains, and remains of two or three hundred individuals have been obtained at this place alone. At other points in the same region, a few remains have been found. A second locality of importance is in Colorado, about three hundred miles south of the most northern known limit of these remains.

The other vertebrate fossils from this horizon are mainly dinosaurs, many of them of gigantic size, but some scarcely larger than the mammals. Crocodiles, turtles, small lizards, and fishes, are also well represented. A single bird (*Laopteryx*), and one small pterodactyl, have likewise been recognized from these deposits. More recently, various bones of small, anourous amphibians (*Eobatrachus agilis*) have been found, the first detected in any Mesozoic formation.* The deposits are lacustrine, as shown by the fresh-water shells they contain.

In investigating these American Jurassic Mammals, it was necessary to compare them, first of all, with those from the same formation in Europe. On this subject, the elaborate memoir of Owen, on British Mesozoic Mammals, was taken as the main authority.†

The first specimens discovered in this country proved to be very near allies of European forms, and most of those since found show a remarkable resemblance to others described by Owen. Some fragmentary specimens cannot indeed be distinguished from the English fossils, but where the remains are more complete, various differences are seen, which appear to be distinctive. A few, well-marked, American genera have no known representatives in Europe, while some forms found there are unknown here.

One difficulty in the investigation of the remains from the two widely-separated regions arises from the necessity of relying mainly upon figures for comparison. Again, these minute, delicate fossils are often embedded in a matrix from which they cannot be removed without great danger of injury or destruction. Hence, the jaws and teeth in many cases must be examined and described from the single side exposed. If

* Proceedings British Association, Aberdeen Meeting, p. 1033, 1885.

† Monograph of the Fossil Mammalia of the Mesozoic Formations. Palæontographical Society, vol. xxiv, London, 1871.

the opposite side of a similar jaw should be shown in another specimen, the two may easily be regarded as distinct. This may also be the case where upper and lower jaws are found separately. Hence, a large amount of material becomes necessary for even a proximate correlation of the closely related forms.

Plagiaulacidæ.

One of the first American specimens discovered resembled strongly the minute lower jaws first described by Falconer, under the name *Plagiaulax*, and since investigated by Owen, Flower, and others, whose discussion of the habits and affinities of these peculiar mammals forms a well-known chapter in the history of palæontology. Of this genus, only the lower jaws were known, and this is one reason for the wide divergence of opinion as to the nature of the animals they represent. The lower jaws found in America were regarded by the writer as indicating a distinct genus, *Ctenacodon*, two species of which he has since described.

Among the separate upper jaws found in the Jurassic of England were two or three described by Owen, under the generic name *Bolodon*, but with no suspicion that they were in any way related to *Plagiaulax*. From American deposits, also, somewhat similar jaws were obtained more recently, and as they were apparently quite distinct from *Bolodon*, they were described by the writer as representing a new genus, *Allodon*. The molar teeth in one specimen resembled those of *Plagiaulax*, and the writer in his description expressed the opinion that *Allodon* should probably be placed in the *Plagiaulacidæ*. A natural inference was that *Bolodon* was the upper jaw of *Plagiaulax*, and *Allodon*, of *Ctenacodon*. However this may be in regard to the European forms, the specimens now known make it clear that the American genera are quite distinct.

The molar teeth of *Allodon* and *Ctenacodon* are of the same general type, and it is still difficult, if not impossible, to distinguish them when detached from the jaws. The premolars, however, and especially the incisors, differ in the two genera, and when well preserved may often be separated with certainty.

Allodon.

In *Allodon*, the superior dentition on each side appears to be as follows:

Incisors 3; canine 0; premolars 5; molars 2.

The lower dentition is uncertain, but is probably the following:

Incisors 1; canine 0; premolars 4; molars 2.

The upper molar series in the type specimen of *Allodon* is well shown in Plate VII, figures 1 and 2. The five premolars have tuberculate crowns, and all appear to be inserted by two fangs. The first and second have each one external, and two internal cones. The third premolar has a small additional cusp. These three premolars diminish in size from before backward. The next premolar, or fourth, is much larger, and has its crown flattened on the inner side. There are three tubercles on the outer border, and four, on the inner margin. The fifth in the series is still larger, and has a more rounded crown. There are three lobes on the outer side, and the same number on the interior face.

The two true molars have low crowns, which are divided into an outer and inner half, by a deep-worn groove. Each half bears three low tubercles, of nearly equal size. The last molar has its longitudinal groove on a line with the inner margin of the other teeth.

The superior incisors of this genus now known are represented in the detached premaxillary of *Allodon fortis*, Plate VII, figures 7–10. The first incisor was very small. The second was the main front tooth, much larger than the third. In the type specimen of *Allodon*, represented in Plate VII, figures 1 and 2, no suture is visible behind the first small tooth (*a*), hence, this may possibly be a weak canine instead of the third incisor. In *Allodon fortis*, figure 7, and also in the type of *Bolodon*, Owen, the suture between the premaxillary and maxillary is distinct.

The large second incisor of *Allodon* is a peculiar tooth, and was evidently exposed to the full wearing action of a strong lower incisor, somewhat similar to that of a rodent. This lower tooth has not been found in place, but the one represented in Plate VII, figures 14 and 15, may, with considerable probability, be referred to this position. The remaining lower teeth have not been found associated with the upper jaws, but they evidently resembled those of *Ctenacodon*, in some of their most important characters.

In comparing *Allodon* with *Bolodon*, we evidently have two nearly related forms. So far as at present known, *Allodon* has three incisors instead of two, a larger number of teeth in the premolar and molar series, and likewise shows other differences of less importance.

The affinities of these peculiar fossils, and the inferences in regard to their habits and food, which may be drawn from the specimens now known, will be fully discussed by the writer elsewhere.

Allodon fortis, sp. nov.

The present species appears to be generically identical with the type specimen of *Allodon laticeps*, but is represented by remains of much larger size. The premaxillary shown on Plate VII, figures 7–10, may be taken as the type specimen. A number of upper molar teeth, and the large lower incisor (figures 14 and 15, of the same Plate), are also referred to this species.

The first incisor in this premaxillary was very small, and situated close to the median line. It is wanting in the present specimen, but its size and position are indicated in the above figures. The second incisor is large and prominent, and is the principal front tooth. It has a distinct crown, which is covered with enamel, and consists of one large main cusp, with a small posterior cone. The lower surface is much worn, evidently by an opposing lower tooth which bore directly against it, from its apex to the small posterior prominence. The sides of the crowns show no signs of wear. The third and last incisor is much smaller, and is separated from the second by a short diastema. It has a distinct crown covered with enamel, but shows no marks of attrition. It is situated a little in advance of the suture with the maxillary, shown in figure 7, *s*, Plate VII.

A second specimen referred to this species is shown in figures 11–13, Plate VII. It is a portion of a left upper jaw containing three premolars, apparently the first, second, and third. The first two of these have a single external cone, and two inner cones, and the second tooth is larger than the first. The third premolar is still larger, unlike the corresponding tooth in *Allodon laticeps*, and has a second exterior cone behind the main one. Above this tooth, there is a large cavity, apparently the entrance of the antorbital foramen. This is shown in figure 11, *f*, Plate VII.

The large lower incisor which met the prominent one above is probably represented in figures 14 and 15. This tooth is faced with enamel in front, and grew from a persistent pulp, like the incisor of a rodent. The summit is incomplete, and hence, the shape of the worn surface cannot be determined.

The specimens here described indicate that *Allodon fortis* was the largest mammal of this group hitherto discovered in the Jurassic. In bulk, it was three or four times as large as *Allodon laticeps*, and about the size of a rat.

The only known remains of this species are from the Atlantosaurus beds of the Upper Jurassic, in Wyoming.

Ctenacodon.

The genus *Ctenacodon* was based upon lower jaws, one of which is represented in Plate VIII, figure 1, and others, in figures 4, 7, and 8. The single, long, pointed incisor, the four, compressed, cutting premolars, and the two, minute, tubercular molars, form together a peculiar dentition. The long, sharp incisor shows no signs of wear whatever, and hence could not be opposed to the large upper incisor of *Allodon*. Its position was close to its fellow, and the two evidently acted together, as indicated in figure 9, Plate VIII. The four premolars form a close-set series, with their upper margins on a curve, all more or less notched. Some specimens, at least, show distinct marks of wear on the outer sides of the crowns, which are sometimes worn to a uniform surface. The two small tuberculate molars are of the *Microlestes* type, with a deep longitudinal groove on the upper surface of the crowns.

The entire upper dentition of *Ctenacodon* is not known with certainty, but it probably corresponded in its main features to that of *Allodon*. A portion of the upper jaw, with typical premolars, is shown in Plate VIII, figures 2 and 3. The posterior premolars, especially the last two, show strong marks of attrition on the inner sides of the crowns, and these were opposed to the compressed premolars below, forming together a most effective apparatus for cutting.

Some of the lower jaws at present referred to *Ctenacodon* apparently show no signs of wear on the premolars, and as the large incisor is not preserved, it is impossible to say definitely that they may not pertain to *Allodon*. It is likewise quite probable that some of the lower jaws considered as *Plagiaulax* may belong with some of the specimens now known as *Bolodon*. The exact correlation of the two forms cannot be determined with certainty until the upper and lower jaws are found together in position.

Ctenacodon may be distinguished from the type of *Plagiaulax* (*P. Becklesii*) in having four premolars instead of three. The summits of these teeth alone are notched, and the sides smooth, not obliquely grooved as in *Plagiaulax*. The condyle, moreover, is separated from the angle of the jaw, not confluent with it. *Ctenacodon*, also, has the angle of the jaw not only strongly inflected, but its outer margin efflected into a wide horizontal shelf, making this one of the most peculiar features of the genus.

The vertical posterior condyle in *Ctenacodon* implies a strong post-glenoid process, that would confine the jaw to a vertical motion.

In *Ctenacodon*, the mental foramen is large, and situated below the middle of the diastema. The dental foramen is under the last molar, but its entrance is partially concealed by a ridge descending from the base of the tooth to the inflected border of the angle.

In none of the specimens of *Ctenacodon* preserved is there any trace of a mylohyoid groove.

Ctenacodon potens, sp. nov.

A third species of *Ctenacodon*, much larger than *C. serratus*, is represented by several jaws and isolated teeth, discovered since the first species was described. The most important of these specimens, which may be taken as the type, is the right upper jaw represented in Plate VIII, figures 2 and 3. The lower jaw with incisor, figured on the same Plate, may also be referred to this species. A second lower jaw in better preservation, but without the incisor, may likewise be included, although somewhat larger in size.

The upper jaw above mentioned agrees in its general shape with that of *Allodon*. It indicates a short, broad skull, with strong, expanded, zygomatic arches. There is a small antorbital foramen, as in *Allodon*. The four premolars present increase in size from before backward. The first and second are of the *Allodon* type. The last two have strong marks of attrition on the inner surface of their crowns, as shown in figure 2, of the same Plate. They differ from the corresponding teeth in *Allodon*, in being more compressed, and adapted to cutting.* There were apparently two true molars, which are wanting in the present specimen, but their position and size are similar to those of the same teeth in *Allodon*.

The left lower jaw represented in figures 7, 8, and 9 shows that the incisor in this species was very large in size, and a most effective weapon. It grew from a persistent pulp, and its massive base extended back under the fourth premolar. The crown is oval in outline at the margin of the jaw, somewhat more compressed above, and sharply pointed at the apex. There is a shallow groove on the outer surface of the lower half of the crown, and a corresponding depression along the middle of its inner face. A careful examination shows no signs of wear on any part of the crown.

The premolars are separated from the incisor by a long diastema. The first premolar is small, without serrations, and is placed close to the second. The latter is larger, inserted by two fangs, and has the summit faintly notched. The third premolar was still larger, but is so much fractured in the

* A somewhat similar tooth of *Microlestes* is figured by Owen in Mesozoic Mammals, Plate I, fig. 16.

present specimen that its form and dimensions are uncertain. The fourth premolar is very large, notched at the summit, and with its outer face showing distinct marks of wear.

The first true molar is small, and its crown much inclined backward. The second true molar is wanting, but its alveoli show that it was also small, and placed below the first molar.

In this species, the series of four lower premolars is placed on a curve, and acts as a single cutting blade against the compressed upper premolars. This curve is completed behind by the two molars, which have their crowns inclined outward.

The second and larger lower jaw referred to this species gives some additional characters. The third and fourth premolars show distinct traces of wear on their outer surfaces. The first true molar is placed obliquely, as in the previous specimen, and has been subjected to much attrition. The last true molar was situated lower than the first, and was also oblique. In *Ctenacodon serratus*, the two lower molars are nearly on a level. The present specimen shows that the angle of the jaw was strongly inflected, and there was likewise a ridge on the opposite outer margin. The coronoid process had its front border more nearly perpendicular than in *Ctenacodon serratus*. There is no trace of a mylohyoid groove.

The known specimens of this species are from the Upper Jurassic deposits of Wyoming.

Dryolestidæ.

The first American mammal found in the Jurassic, and a large proportion of those since discovered, belong to a peculiar family which the writer has called the *Dryolestidæ*. It includes several genera and numerous species from this country, and is likewise represented among the forms found in Europe.

The type species of the group, *Dryolestes priscus*, was based upon a characteristic lower jaw, although the specimen was imperfect. A nearly complete lower jaw of the species is represented on Plate IX, figure 2. An allied species, *Dryolestes vorax*, is shown on the same Plate, by figures 3 and 4. *Stylacodon*, *Asthenodon*, and *Laodon*, other genera of this family, are likewise represented on the same Plate.

The upper jaws of several genera of this family are now known with tolerable certainty, and these will be figured and described fully in the Memoir now in preparation.

All the genera of this family have more than the typical number of teeth (44), and the general characters of the inferior dentition are well shown in Plate IX. The lower teeth form a close-set series, without diastemas, or marked interspaces.

There are three, or four, incisors, and in those preserved, each has a distinct crown, and the series diminishes in size from in

front backward. The canine is inserted by two fangs, more or less distinct, and in most forms, its crown is prominent and trenchant. Three or four premolars follow, increasing in size backward, with the last usually very prominent, and in some forms, larger than the canine. These premolars all have two roots, and a compressed crown. All have one main cusp, and a small posterior heel. There is usually a small anterior cusp, especially on the posterior teeth.

The molar teeth are from six to eight in number, and are essentially identical in form, and usually distinct from the premolars. The crown consists of one main external cone, high and pointed, and three internal cusps, which vary much in development in the different genera. Seen from the outside, these teeth appear to be inserted by a single fang, but, in most cases, each has two roots, although these are nearly or quite connate. When the jaw is embedded in the matrix, and the diminutive teeth uncovered as far as safety will permit, the features of one side only of the molars can be determined. Thus in figure 1, Plate IX, the outer exposed side of one lower jaw (*Stylacodon*) is shown, while in figure 2, the inner side of another jaw (*Dryolestes*) is represented. In figures 3 and 4, the two sides of the same jaw are placed together, and the main characters of the lower molar teeth of *Dryolestes* are thus made evident.

There are seven superior molars, and these have one main inner cone, and three outside cusps that vary in size and proportions in the different genera.

Dryolestes and Stylacodon.

The two genera most nearly allied in dentition are *Dryolestes* and *Stylacodon*, typical examples of which are shown on Plate IX. The number of lower teeth in the best preserved specimens appears to be the same in each, while the incisors, canine, and four premolars, show no marked differences. In *Dryolestes*, the eight molars which follow are all of one type, and differ but little except in size. All have the inner middle cone of the crown as high as, or higher than the outer main cone. In *Stylacodon*, the first two of these teeth resemble the anterior premolars in shape, and like them show from the outside double fangs. The main external cone is quite as high as the opposite cusp.

In *Dryolestes*, moreover, the lower jaw is comparatively short and massive, deep below the molar teeth, with its lower margin strongly convex. The condyle in the best preserved specimen is concave transversely, and has its lower margin nearly on a line with the summits of the molar teeth.

In *Stylacodon*, the lower jaw is long and slender, and constricted in front of the coronoid process, which slopes well upward and backward. The condyle is convex transversely, and placed considerably above the line of the teeth. The jaw is shallow below the molars, scarcely exceeding the height of the teeth themselves, while the lower border in this region is nearly straight. These differences may be readily seen in the two specimens shown on Plate IX, figures 1 and 2. The mylohyoid groove is well developed in both genera, and its position is essentially the same in each.

In *Dryolestes*, the mental foramen is below the first premolar. The dental foramen is beneath the front margin of the coronoid process, and at this aperture, the mylohyoid groove begins.

ASTHENODON.

The genus *Asthenodon*, the type species of which is described below, agrees with the above genera in the more important characters of the lower dentition, but differs, in having the entire series of teeth much more uniform in size, and but eleven teeth behind the canine. The type of this species is the lower jaw shown in Plate IX, figure 7. A second specimen referred to this species is the anterior part of another jaw, shown in figure 6. The former jaw shows a weak canine (*a*), followed by three premolars, each with two fangs. Behind these, in place of the large, trenchant premolar seen in *Dryolestes* and *Stylacodon*, is a small tooth, which from its shape may be regarded as the first molar. The remaining teeth agree in their more important characters with the corresponding molars of *Dryolestes*. The second specimen, figure 6, shows a similar weak canine, and, in front of it, the four incisors in place, increasing rapidly in size forward, the front one being larger than the canine.

Asthenodon segnis, gen. et sp. nov.

In the genus *Asthenodon*, the inferior dentition on each side is as follows:

Incisors 4; canine 1; premolars 3; molars 8.

The largest tooth in the entire lower series is the first incisor, Plate IX, figure 6, 1. The remaining incisors decrease in size backward, as shown in the same figure, 2, 3, and 4. The canine (*a*) is small and weak, and its crown resembles that of the incisors. It is implanted by two roots, which are nearly connate. The three premolars behind the canine have each two fangs, and increase in size from first to last, as shown in figure 7, of the same Plate. The following seven teeth, judging from

the shape, are molars, and behind them is the alveole of one more. These molars agree in general form with those of *Dryolestes*. The form of the lower jaw also is similar in the two genera. The upper jaw of this genus is not known.

The specimens representing this species indicate an animal about the size of a weasel. They are from the Atlantosaurus beds of Wyoming Territory.

Laodon.

A fourth genus, *Laodon*, while agreeing in the general type of lower molar teeth with the above forms, differs widely from them in other respects. The molars in this genus have the outer main cone high and pointed, as in the above genera, but the inner opposite cusp is greatly reduced in size, as shown in the type specimen represented in Plate IX, figure 5. There appear to have been eight molar teeth, six of which are well preserved. In front of these, are two premolars of nearly equal size, and between these and the canine, there were apparently three more, each with two fangs, making thirteen teeth in the premolar and molar series. The canine had two roots, and the last incisor was placed closely in front of it.

In this specimen, the dental foramen is situated below the summit of the coronoid process. Its aperture is placed obliquely, opening backward and upward, and from its outer margin, the deep mylohyoid groove extends forward and downward, rapidly descending below the lower border of the ramus.

This lower jaw is intermediate in form between *Dryolestes* and *Stylacodon*. It has the slender straight ramus of *Stylacodon*, with even a stronger constriction behind the molar teeth, but the jaw is deeper below the molar series, and the lower margin is convex, as in *Dryolestes*. The molar teeth resemble those of *Peraspalax*, Owen, but in that genus there is a less number of teeth, and other features not seen in the present specimen.

The upper jaw of this genus has not yet been identified.

Laodon venustus, gen. et sp. nov.

In the type specimen of this species, the inner side only of the lower jaw is shown. The alveolar border is nearly straight, while the lower margin is strongly convex. The anterior portion of the ramus is very shallow, but little, if any, deeper than the crowns of the teeth it contained. There is a well-marked mylohyoid groove, which begins at the dental foramen, and extends forward and downward, until it is lost below, directly under the second molar. The angle of the jaw extends well backward, and was not inflected, although somewhat thickened

along the lower margin. The pterygoid fossa is deep and wide. The coronoid process was large, but its exact form cannot be determined.

The type specimen of the present species is from the Upper Jurassic deposits of Wyoming.

Diplocynodontidæ.

A third group of Jurassic Mammals is known at present from three genera, which have been found only in this country. The most typical form, *Diplocynodon*, is represented on Plate X, figure 3, by the specimen first described. This fossil indicates one of the largest mammals yet found in the Jurassic. In this genus, there were at least three lower incisors, directed well forward. The canine is very large, elevated, and trenchant, and inserted by two strong fangs. Behind this, there are twelve teeth, all essentially of the same type, so that, from the outer side alone, it is difficult, if not impossible, to distinguish the premolars from the molars. The crowns of these teeth are composed of a main external cone, with a small, elevated lobe in front, and a lower one behind. This is repeated on a reduced scale on the inner side, except that the posterior cusp is rudimentary, or wanting. The antero-posterior faces of the crowns are deeply excavated, and grooved.

The jaw is elongate, and gently curved below. The coronoid process is large, and elevated. The condyle is placed very low, nearly on a line with the teeth. The angle of the jaw is produced into a distinct process (*d*), the lower margin of which bends outwards, although the process as a whole has a slight inward direction.

In *Diplocynodon victor*, the mental foramen is beneath the interspace between the second and third premolars. The dental foramen is large, and is situated intermediate between the last molar and the angle of the jaw. From its front margin, the narrow straight mylohyoid groove extends forward, nearly parallel with the lower margin of the ramus.

An upper jaw referred to this species contains the canine and eight succeeding teeth in excellent preservation. The canine is very large, and has two distinct fangs. The molar teeth have one, main, external cone, and two lateral cusps, which rise from a strong basal ridge. On the inner side, there is one main cone, with a small posterior heel. The outer face and the sides of the upper molars are deeply sculptured with irregular grooves.

The European genus *Amphitherium* may possibly belong to this family, but the lower canine has only a single root, and the molars appear quite different from those of the American forms.

Docodon.

Another genus (*Docodon*) of this family may be distinguished from *Diplocynodon* by having, in the lower jaw behind the canine, eleven teeth instead of twelve. The canine has two fangs, as in the latter genus, and the molar teeth correspond closely in form. The symphysis is very long, and the mylohyoid groove extends forward to its upper border. The type specimen of this genus is shown in Plate X, figure 2.

In *Docodon*, the dental foramen is further back than in *Diplocynodon*, and the mylohyoid groove, leading out of it, is deep and straight as far as the last premolar.

Enneodon.

A third genus, *Enneodon*, described below, is represented by two specimens, one of which is shown on Plate X, figure 4. The lower jaw is comparatively short and robust, and contained only nine post-canine teeth, all of the same type.

Enneodon crassus, gen. et sp. nov.

The canine in *Enneodon* is large, and, as in the other genera of this family, is inserted by two well-separated fangs. Seen from the outside, its crown resembles that of a true molar, but the anterior lobe is wanting. The second premolar is larger than the first, not smaller, as in the type of *Diplocynodon*. The premolars, although of the same general form as the molars, have the surface of the crown more grooved, or striate.

Enneodon affinis, sp. nov.

A second specimen of this genus agrees with that last described in the main features of its dentition, but the lower jaw is less robust. The canine is also more slender, and there is a small diastema behind it. The first three premolars increase in size backward, but are all of similar form. The angle of the jaw is considerably below the lower margin of the ramus.

The principal dimensions of this specimen are as follows:

Space occupied by nine premolar and molar teeth	16·mm
Depth of jaw below first premolar	2·
Depth of jaw below first molar	3·25
Height of first premolar above jaw	1·5
Height of second molar above jaw	2·
Antero-posterior diameter of second molar	2·

The fossils on which the two species of *Enneodon* are based were found in the Atlantosaurus beds of the Upper Jurassic, in Wyoming.

Spalacotheridæ.

The type genus of this family is *Spalacotherium* of Owen, but it is probable that he included more than one generic form under this name, in the various specimens described. In this country, one well-preserved jaw has been found, which appears to indicate a distinct genus (*Menacodon*), and is described below. This specimen is represented on Plate X, figures 5 and 6.

In the typical specimens of *Spalacotherium*, the premolar and molar teeth are ten in number, and of the same general form. The crown consists of one, main, external cone, high and pointed, and two, short, inner cusps, nearly equal in size, in front of and behind the main cone. The canine has two fangs, and there is little or no diastema behind it.

In *Menacodon*, the molars have the same general form, but there appear to be but seven in the post-canine series. The crowns also are shorter and more robust. The canine is small, and has two roots.

Menacodon rarus, gen. et sp. nov.

In this species, the lower jaw is comparatively slender, and its inferior border is strongly convex, longitudinally. The canine was small, and directed well forward. The first three premolars are separated slightly from the canine, and from each other. The three following teeth, which may be regarded as true molars, are larger and more elevated, and behind these was the last molar, somewhat smaller in size.

In the type specimen of *Menacodon*, there is no sharply defined mylohyoid groove, but a shallow depression takes its place, as indicated in Plate X, figure 6.

In *Spalacotherium*, there is a well-defined mylohyoid groove.

The unique specimen on which the present species is established was found in the Upper Jurassic of Wyoming.

Tinodontidæ.

This family is well represented by American forms, one of which, the type species of *Tinodon*, is shown on Plate X, figure 1. *Phascolotherium*, Owen, appears from its dentition to be an allied form, but differs in several important points, and may yet be found to represent a distinct family. The premolar and molar teeth have nearly the same form in both genera, but in *Tinodon*, there is a larger number of post-canine teeth. The coronoid process, also, is vertical, and the angle of the jaw is not inflected. The premolars have the same general shape as the molars, the crowns being composed essentially of three

pointed cusps, one, main, outer cone, and two, smaller cusps, one in front and one behind, on the inner side. There is a strong cingulum on the inner surface, which may develop into an anterior lobe, or posterior heel. The mylohyoid groove is distinct. The condyle in *Tinodon* is rounded, and somewhat transverse, and is separated from the jaw by a distinct neck.

In *Tinodon bellus*, the dental foramen is large (Plate X, figure 1, *f*), and looks downward and backward. It is placed somewhat behind the anterior margin of the coronoid process, and somewhat above the middle line of the ramus. The deep mylohyoid groove (*g*) leads from this opening, forward and downward.

Triconodontidæ.

Another family related to the one last described is represented by the genus *Triconodon* of Owen, and by one or two American forms. In this group, the premolars are unlike the molars. The latter are large, and their crowns are composed of three, nearly equal, trenchant cusps. The premolars are compressed and trenchant, but lack the anterior cusp. There is apparently more than one genus included under the specimens referred by Owen to *Triconodon*, but more specimens will be required to separate them.

Priacodon, gen. nov.

One of the American forms, which appears to be generically distinct from the type of *Triconodon*, is represented below, on Plate X, figure 9, under the name *Priacondon ferox*. The type specimen, on which it is based, was originally placed by the writer in the genus *Tinodon*, and the species named *Tinodon ferox*. This specimen is a right lower jaw, with most of the teeth in position. There are three premolars, and four molars. The premolars have one main cone, pointed and compressed, with a low cusp in front, and a larger one behind. The last premolar is large. The penultimate molar has four distinct cones instead of three. The canine was large, and directed well forward. The coronoid process is high, and inclined backward. The mylohyoid groove is nearly parallel with the lower margin of the jaw, and extends forward to the symphysis. The latter is strongly marked.

Paurodontidæ.

A peculiar genus, *Paurodon*, widely different from any form hitherto found in this country or Europe, is represented at present by a single specimen, a left lower jaw. This is shown

on Plate X, figures 7 and 8. The entire premolar and molar series consists of only six teeth, the main features of which are seen in the figures cited. The canine is large, nearly erect, and is apparently inserted by a single fang. There is a distinct diastema between this and the first premolar. The latter is small. The lower jaw is short and massive, and there is a deep mylohyoid groove (*g*).

The molar teeth of *Paurodon* appear to agree in the general features of their crowns with those of *Achyrodon* and *Peralestes*, but the figures given by Owen of the specimens described under these names show them to be quite distinct from the present genus.

Paurodon valens, gen. et sp. nov.

In this genus, there were apparently two lower premolars, and four molars, all separated somewhat from each other. The premolars have a single main cusp, and a low posterior heel. Each is implanted by two roots. The molars have a single main external cone, and two low inner cusps. The mylohyoid groove extends from the pterygoid fossa to the symphyseal surface, which is large. The mental foramen is below the diastema between the canine and the first premolar.

The upper jaw of this peculiar fossil is not known.

The type specimen of this unique form is from the Upper Jurassic deposits of Wyoming Territory.

The main object of the present article is to present a typical series of the remains of known American Jurassic mammals. A discussion of the closer relations of these to the mammals from the same formation in Europe, as well as to both older and more recent forms, will be reserved for the Memoir now in course of preparation.

The vertebræ, limb bones, and other parts of the skeleton of mammals, found with the jaws and teeth here described, cannot yet be definitely associated with the latter, but an attempt to do this will be made in the Memoir.

The genera and species of American Jurassic mammals now known are given in the list below. All have been described by the writer, in this Journal. One figure, at least, of a typical form of each new genus proposed, has also been given, either in the original description, or in the present article.

The list is as follows:

Plagiaulacidæ.

Allodon laticeps.	Amer. Jour. Sci.,	vol.	xxi,	p. 511, 1881.
" fortis.	"	"	xxxiii,	p. 331, 1887.
Ctenacodon serratus.	"	"	xviii,	p. 396, 1879.
" nanus.	"	"	xxi,	p. 512, 1881.
" potens.	"	"	xxxiii,	p. 333, 1887.

Dryolestidæ.

Dryolestes priscus.	Amer. Jour. Sci.,	vol.	xv,	p. 459, 1878.
" vorax.	"	"	xviii,	p. 215, 1879.
" arcuatus.	"	"	xviii,	p. 397, 1879.
" obtusus.	"	"	xx,	p. 237, 1880.
" gracilis.	"	"	xxi,	p. 513, 1881.
Stylacodon gracilis.	"	"	xviii,	p. 60, 1879.
" validus.	"	"	xx,	p. 236, 1880.
Asthenodon segnis.	"	"	xxxiii,	p. 336, 1887.
Laodon venustus.	"	"	xxxiii,	p. 337, 1887.

Diplocynodontidæ.

Diplocynodon victor.	Amer. Jour. Sci.,	vol.	xx,	p. 235, 1880.
Docodon striatus.	"	"	xxi,	p. 512, 1881.
Enneodon crassus.	"	"	xxxiii,	p. 339, 1887.
" affinis.	"	"	xxxiii,	p. 339, 1887.

Spalacotheridæ.

Menacodon rarus. Amer. Jour. Sci., vol. xxxiii, p. 340, 1887.

Tinodontidæ.

Tinodon bellus.	Amer. Jour. Sci.,	vol.	xviii,	p. 216, 1879.
" robustus.	"	"	xviii,	p. 397, 1879.
" lepidus.	"	"	xviii,	p. 398, 1879.

Triconodontidæ.

Triconodon bisulcus.	Amer. Jour. Sci.,	vol.	xx,	p. 237, 1880.
Priacodon ferox.	"	"	xxxiii,	p. 341, 1887.
(*Tinodon ferox*).	"	"	xx,	p. 236, 1880.

Paurodontidæ.

Paurodon valens. Amer. Jour. Sci., vol. xxxiii, p. 342, 1887.

None of the known Mesozoic mammals appear to have been truly herbivorous. *Stereognathus*, which has been considered as such, from its molar teeth, cannot fairly be regarded as evidence, since it was based, not upon part of a lower jaw, as described by Owen, but upon a fragment, evidently the posterior portion of the maxillary, and the teeth resemble the superior molars of some insectivorous forms.

Nearly all the mammals older than the Tertiary, judging from their dentition alone, may have lived mainly upon insects, with such accessory diet as modern Insectivores affect. The *Plagiaulacidæ*, however, show evidence of marked adaptation to some peculiar food, whether animal or vegetable cannot yet be determined with certainty. Now that the upper teeth of *Ctenacodon* are known, and trenchant teeth are found opposed to the lower cutting premolars, and tubercular molars to those below, the problem is simplified, but not solved. The evidence at present points to an animal, rather than to a vegetable, diet for all the *Allotheria*.

It is not improbable that there was a gradual change in diet in the later forms, until vegetable food predominated. The fact that the Tertiary genus *Neoplagiaulax*, Lemoine, has only a single lower premolar coincides with this view, and if *Hypsiprymnus* is a still later descendant, the additional molars, and other herbivorous features, may be the result of this gradual change.

The few Mammals known from the Trias may be placed in two families, *Dromotheridæ*, including the American specimens, and *Microlestidæ*, those of the old world. They are all quite distinct from any of the Jurassic forms, either those found in this country or in Europe. Below the Trias, no Mammals have hitherto been discovered; and none are known with certainty from the Cretaceous.

Mesozoic Mammals have very generally been referred hitherto to the *Marsupialia*. An examination of the known remains of American Mesozoic Mammalia, now representing upwards of two hundred distinct individuals, has convinced the writer that they cannot be satisfactorily placed in any of the present orders. This appears to be equally true of the European forms which the writer has had the opportunity of examining. With a few exceptions, the Mesozoic mammals best preserved are manifestly low generalized forms, without any distinctive Marsupial characters. Many of them show features that point more directly to Insectivores, and present evidence, based on specimens alone, would transfer them to the latter group, if they are to be retained in any modern order. This, however, has not yet been systematically attempted, and the known facts are against it.

In view of this uncertainty, it seems more in accordance with the present state of science, to recognize the importance of the generalized characters of these early mammals, as at least of ordinal value, rather than attempt to measure them by specialized

features of modern types, with which they may have little real affinity. With the exception of a very few, aberrant forms, the known Mesozoic mammals may be placed in a single order, which the writer has named *Pantotheria*.* Some of the more important characters of this group are as follows:

(1.) Cerebral hemispheres smooth.
(2.) Teeth exceeding, or equalling, the normal number, 44.†
(3.) Canine teeth with bifid or grooved roots.†
(4.) Premolars and molars imperfectly differentiated.
(5.) Rami of lower jaw unankylosed at symphysis.
(6.) Mylohyoid groove on inside of lower jaw.
(7.) Angle of lower jaw without inflection.
(8.) Condyle of lower jaw near horizon of teeth.
(9.) Condyle vertical or round, not transverse.

The generalized members of this order were doubtless the forms from which the modern, specialized, Insectivores, at least, were derived.

Another order of Mesozoic mammals is evidently represented by *Allodon*, *Bolodon*, *Ctenacodon*, *Plagiaulax*, and a few other genera. These are all highly specialized, aberrant, forms, which apparently have left few, if any, descendants later than the Tertiary. This order, which the writer has termed the *Allotheria*,‡ can be distinguished from the previous group by the following characters:

(1.) Teeth much below the normal number.
(2.) Canine teeth wanting.
(3.) Premolar and molar teeth specialized.
(4.) Mylohyoid groove wanting.
(5.) Angle of lower jaw distinctly inflected.

These characters alone do not separate the *Plagiaulacidæ* and *Microlestidæ* from some of the Marsupials, and the facts now known seem to prove that they belong in that group, where they represent, at least, a well-marked sub-order.

Of the two families of Triassic Mammals now known, the *Dromotheridæ* may be placed in the order *Pantotheria*, and the *Microlestidæ*, in the *Allotheria*. According to present evidence, the former were probably placental, and the latter, non-placental, and marsupial.

* This Journal, vol. xx, p. 239, 1880.
† The genus *Paurodon* may be an exception.
‡ This Journal, vol. xx, p. 239, 1880.

The modern Placental mammals were evidently not derived from Marsupials, as is generally supposed. Each group has apparently come down to the present time, by separate lines, from primitive, oviparous, forms, of which, the living Monotremes may be the more direct but specialized representatives. Among the diversified members of Placental mammals, the Insectivores are probably the nearest to the early type, and hence they show many features seen in the Jurassic and Triassic mammals of the order *Pantotheria*.

Among the various existing Marsupials, the Rat-Kangaroos, (*Hypsiprymnidæ*) appear to be nearest to the oldest known forms represented in the order *Allotheria*, but future discoveries may, at any time, bring to light new Mesozoic mammals allied to other Marsupials.

So far as at present known, the two great groups of Placental and Non-placental mammals appear to be distinct in the oldest known forms, and this makes it clear that, for the primitive generalized forms (*Hypotheria*), from which both were derived, we must look back to the Palæozoic.

Yale College, New Haven, March 16, 1887.

EXPLANATION OF PLATES.

PLATE VII.

FIGURE 1.—Left upper jaw of *Allodon laticeps*, Marsh: outer view.

FIGURE 2.—The same specimen; seen from below.

FIGURE 3.—Left upper jaw of same species; inner view.

FIGURE 4.—The same specimen: seen from below.

FIGURE 5.—Left upper jaw of same species; outer view.

FIGURE 6.—The same specimen; seen from below.

FIGURE 7.—Right premaxillary of *Allodon fortis*, Marsh; outer view.

FIGURE 8.—The same specimen; seen from below.

FIGURE 9.—The same specimen; seen from in front.

FIGURE 10.—The same specimen; inner view.

FIGURE 11.—Portion of left upper jaw of *Allodon fortis*; outer view.

FIGURE 12.—The same specimen; seen from below.

FIGURE 13.—The same specimen; inner view.

FIGURE 14.—Lower incisor of *Allodon fortis*; side view.

FIGURE 15.—The same incisor; seen from in front.

a, last incisor; *a''*, second premolar; *b*, fourth premolar; *b'*, third premolar; *c*, second true molar; *c'*, first molar; *f*, antorbital foramen; *m*, malar arch; *s*. suture with maxillary.

Figures 1–4 are four times natural size; 5 and 6, six times natural size; 7–15, three times natural size.

PLATE VIII.

FIGURE 1.—Right lower jaw of *Ctenacodon serratus*, Marsh; outer view.

The small figure is natural size, and the larger one is magnified four diameters.

FIGURE 2.—Right upper jaw of *Ctenacodon potens*, Marsh; inner view.

FIGURE 3.—The same jaw; seen from below.

FIGURE 4.—Left lower jaw of *Ctenacodon serratus*; inner view.

FIGURE 5.—Incisor, probably of same species; seen from in front.

FIGURE 6.—The same incisor; seen from the side.

FIGURE 7.—Left lower jaw of *Ctenacodon potens*; outer view.

FIGURE 8.—The same jaw; inner view.

FIGURE 9.—The same jaw; front view, with its fellow restored in place.

In figures 2 and 3, *a'*. first premolar; *b*, fourth premolar; *c*, second molar; *m*, malar arch. In the lower jaws, *a*, incisor; *b*, condyle; *c*, coronoid process; *m*, molar; *r*, root of incisor; *s*, symphyseal surface.

Figures 2, 3, 5, and 6, are four times natural size, and figures 4, 7, 8, and 9, are three times natural size.

PLATE IX.

FIGURE 1.—Left lower jaw of *Stylacodon gracilis*, Marsh; outer view.

FIGURE 2.—Left lower jaw of *Dryolestes priscus*, Marsh; inner view.

FIGURE 3.—Left lower jaw of *Dryolestes vorax*, Marsh; outer view.

FIGURE 4.—The same jaw; inner view.

FIGURE 5.—Left lower jaw of *Laodon venustus*, Marsh; inner view.

FIGURE 6.—Left lower jaw of *Asthenodon segnis*, Marsh; anterior part, outer view.

FIGURE 7.—Right lower jaw of same species; outer view.

a, canine; *b*, condyle: *c*, coronoid process; *d*, angle; *g*, mylohyoid grove; *s*, symphyseal surface.

All the figures are three times natural size, except figure 5, which is four times natural size.

PLATE X.

FIGURE 1.—Right lower jaw of *Tinodon bellus*, Marsh; inner view.

FIGURE 2.—Right lower jaw of *Docodon striatus*, Marsh; inner view.

FIGURE 3.—Right lower jaw of *Diplocynodon victor*, Marsh; outer view.

FIGURE 4.—Right lower jaw of *Enneodon crassus*, Marsh; outer view.

FIGURE 5.—Left lower jaw of *Menacodon rarus*, Marsh; outer view.

FIGURE 6.—The same jaw; inner view.

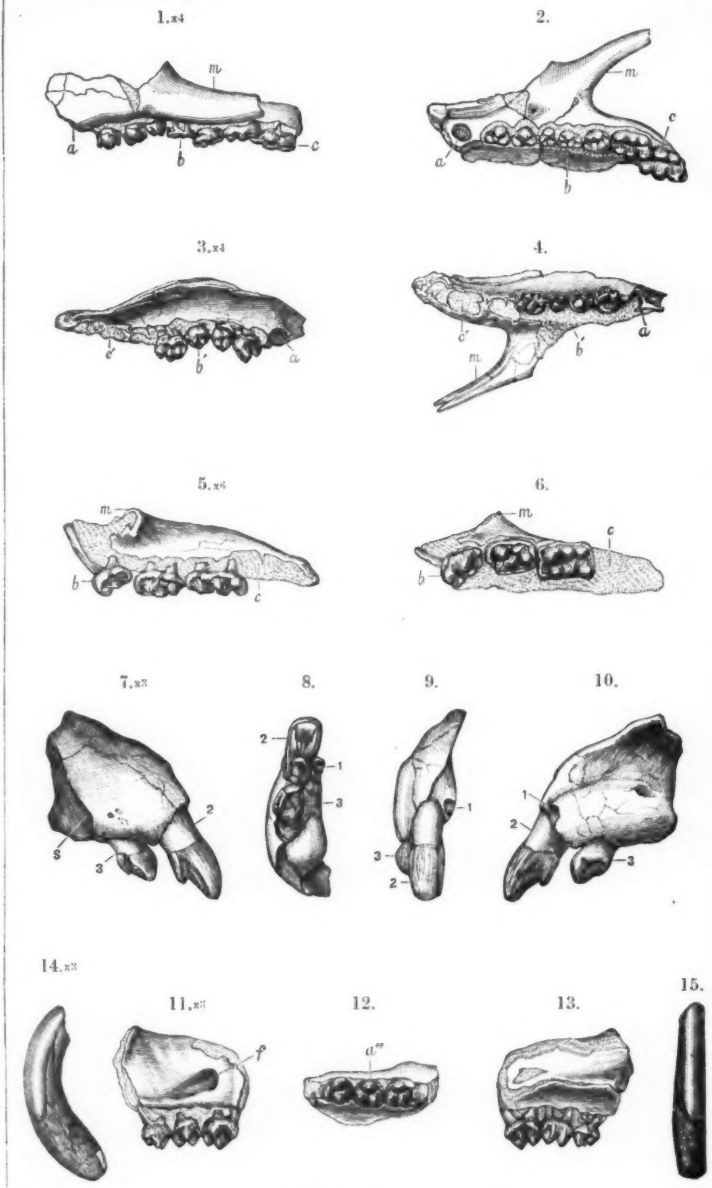
FIGURE 7.—Left lower jaw of *Paurodon valens*, Marsh; outer view.

FIGURE 8.—The same jaw; inner view.

FIGURE 9.—Right lower jaw of *Priacodon ferox*, Marsh; inner view.

a, canine; *b*, condyle; *c*, coronoid process; *d*, angle; *f*, dental foramen; *g*, mylohyoid groove; *s*, symphyseal surface.

Figures 2 and 3 are twice natural size, and the others, three times natural size.



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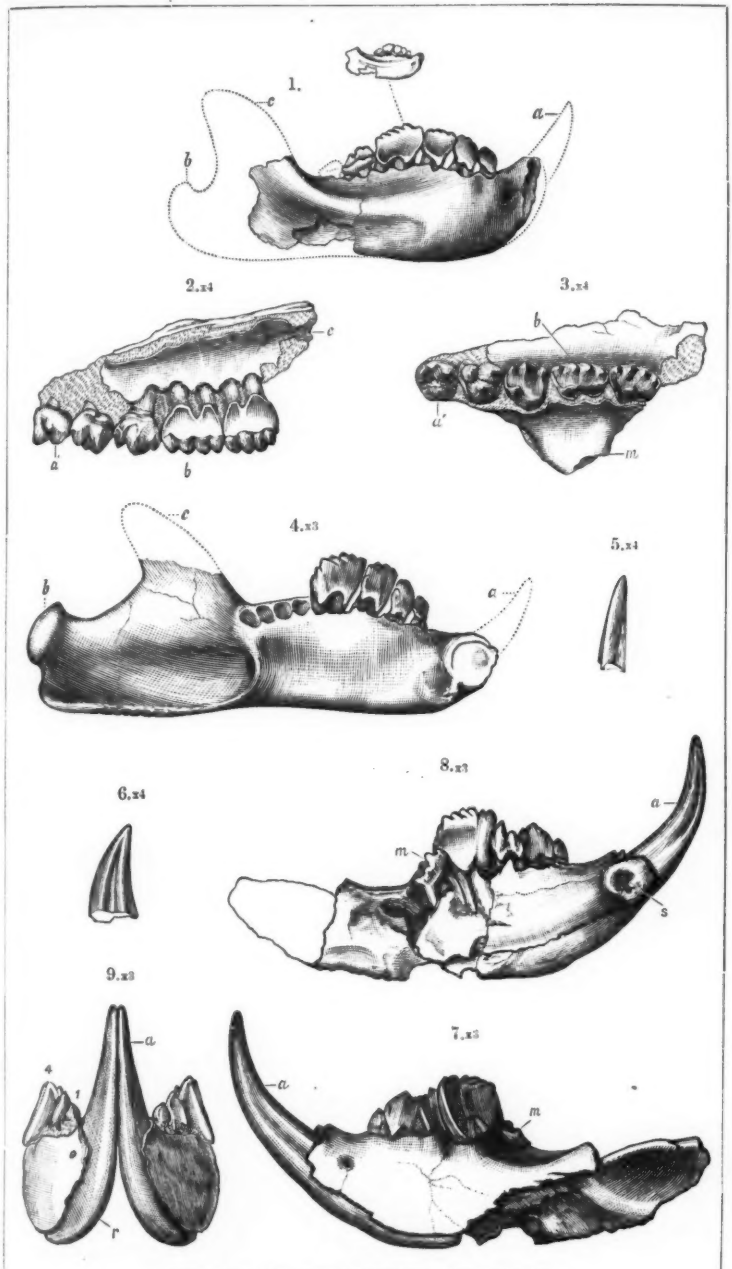

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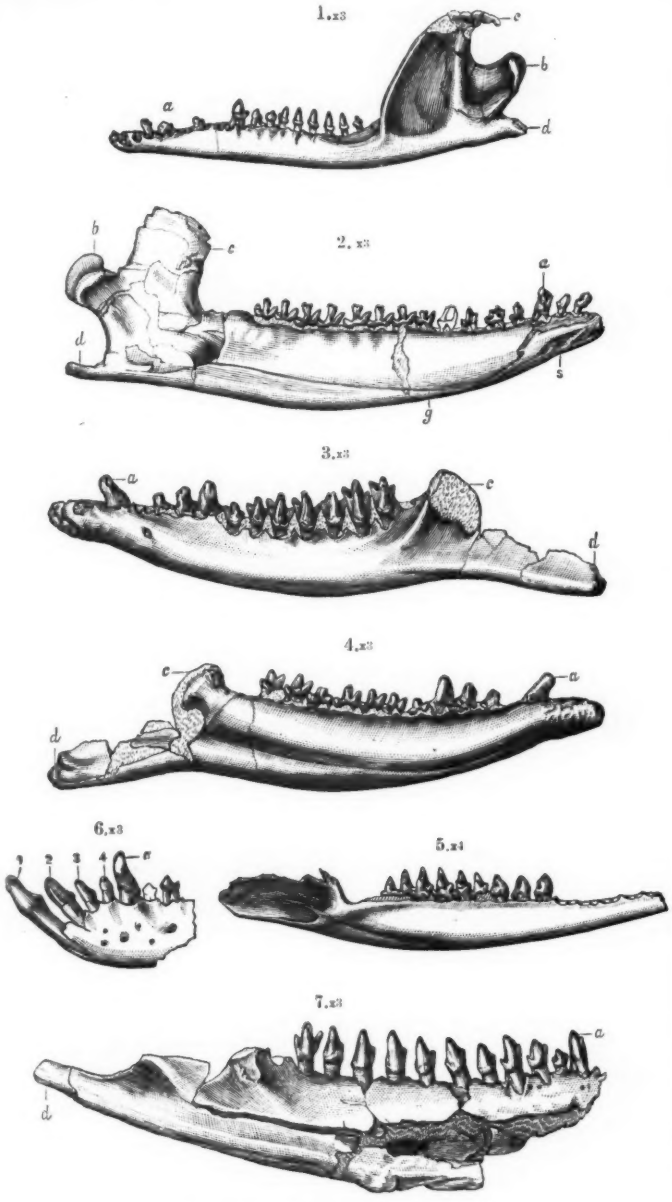

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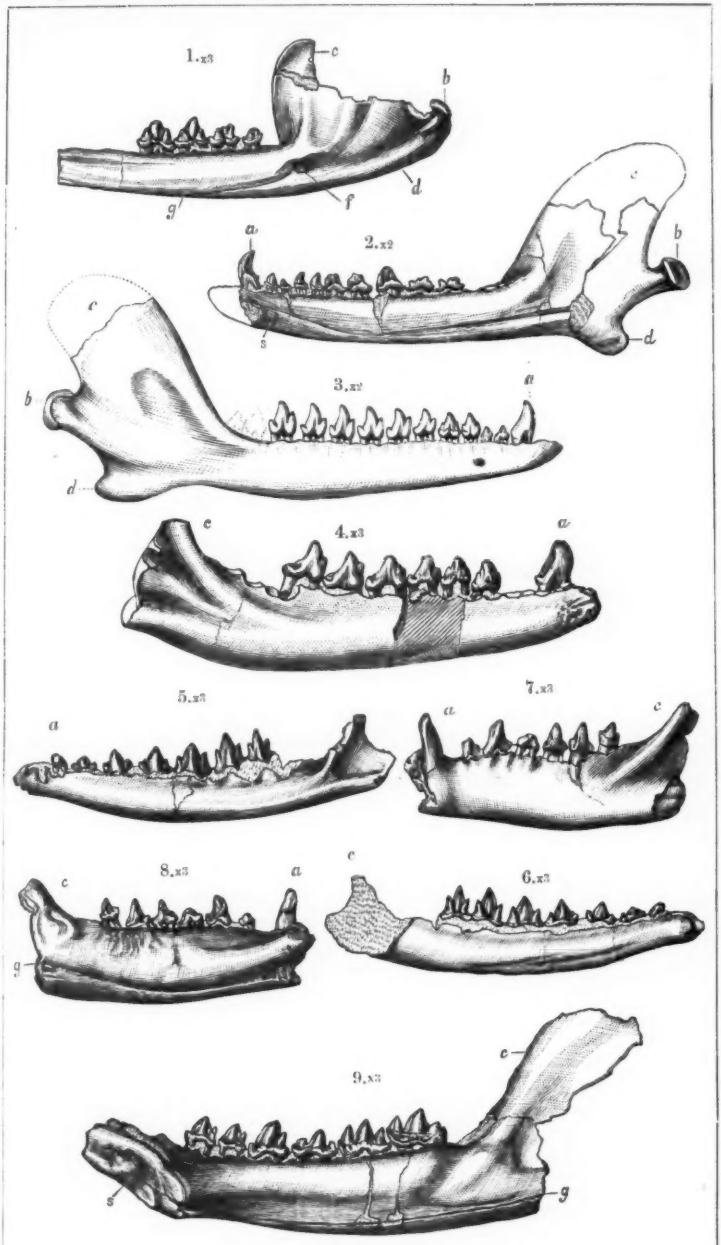

AMERICAN JURASSIC MAMMALS.

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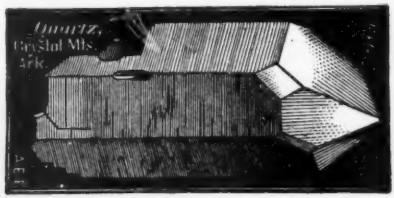

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